Nitrogen Removal Performance of Three On-Site Alternative Wastewater Treatment Systems in Montana

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1. INTRODUCTION

In 1973 the Montana Legislature passed the Montana Clean Water Act (CWA). The CWA called for a careful evaluation of all new and increased sources of pollution with the potential to enter state waters, both groundwater and surface water, and cause degradation. The Montana Department of Environmental Quality (MDEQ) began enforcing the CWA requirements in 1993. Specifically, the MDEQ Subdivision Section began requiring that new subdivisions, and the development of existing parcels not previously approved by MDEQ, provide evidence that the installation of onsite wastewater systems (OWS) on those parcels would not cause degradation of state waters.

Much of the new subdivision in Montana is occurring outside of the boundaries of cities and towns. Most rural areas rely on individual groundwater wells for domestic water and OWS for wastewater treatment and disposal. The wastewater discharged by OWS can cause degradation of both ground and surface water by elevating nitrogen levels, bacterial and viral counts, and phosphorous levels. Because it was not practical to address all of these possible contaminants, MDEQ focused on nitrogen. Elevated levels of nitrogen as nitrates in drinking water are associated with "blue baby" syndrome or methemoglobenemia. Methemoglobenemia is a potentially fatal condition in which the hemoglobin in the blood of infants cannot transport oxygen through their bodies. The MDEQ defined the predicted concentration of nitrogen as nitrates in the groundwater after development to be an indicator of degradation.

To determine if a new OWS will significantly degrade the groundwater, the nitrogen level in the groundwater after development must be predicted. To make this prediction, the amount of nitrogen in the wastewater discharged by the OWS to the environment must be known. MDEQ established theoretical amounts of nitrogen expected to be discharged by two types of OWS's; standard OWS's and level II systems or "advanced" OWS's. A standard OWS generally consists of a septic tank and a drainfield. Level II systems or advanced OWS's are designed specifically to reduce the concentration of nitrogen in wastewater prior to disposal.

If significant degradation is predicted to occur when a standard OWS is used, the developer has the option to use a level II type treatment system to reduce the predicted degradation to a level defined as non-significant. Two systems, intermittent sand filters (ISF) and raised sand mounds (RSM), are designated as level II type treatment systems by MDEQ.

These two approved level II type treatment systems cost two to three times more to install than standard OWS's and the nitrogen removal performance of the systems has been questioned. The systems both provide excellent nitrification (conversion of nitrogen as ammonia to nitrogen as nitrates) and some total nitrogen removal but are unlikely to meet the level II requirements. Consequently, a large amount of money was being spent to install ISF's and RSM's that were most likely not providing the level of nitrogen removal expected.

Unfortunately, little nitrogen removal performance data for other advanced systems is available, especially from systems operated under conditions/climates similar to Montana. This study was

intended to provide that data. The data is expected to be used by MDEQ and developers in the process of designating advanced OWS's as level II type systems.

1.1 Purpose

The general purpose of this project is to provide Montana specific performance data for advanced OWS's designed to remove nitrogen from residential wastewater. This project provides nitrogen removal data from three advanced OWS's operated in Montana. The project is designed to provide regulators and developers with reliable data regarding the expected nitrogen concentration of the effluent leaving these systems and entering the environment.

The workplan objectives are as follows:

1. Collect nitrogen effluent quality data from onsite sewage treatment and disposal systems operated in Montana at single family residences.
2. Evaluate efficiency and effectiveness of each system for nitrogen removal.
3. Evaluate cost (both capital and operation and maintenance) versus treatment benefit of each system as a function of nitrogen removal.
4. Provide conclusions and recommendations regarding each system's potential for future use in Montana for nitrogen removal.

1.2 Scope

The scope of the project is defined by the following tasks:

1. Identify OWS's to be monitored for nitrogen removal performance.
2. Select a site for each OWS.
3. Install OWS and monitoring accesses.
4. Begin operating each OWS as per the designers' specifications to achieve maximum nitrogen removal.
5. Monitor the water quality at both the inflow and outflow of the nitrogen treatment devices.
6. Troubleshoot poor performance and adjust system operation if necessary in an attempt to improve system performance.
7. Document conditions surrounding satisfactory performance.
8. Evaluate system performance after 12 months of monitoring and determine if an additional 12 months of monitoring is merited.
9. Evaluate system performance after 24 months of monitoring.
10. Prepare final report.

1.3 Nitrogen Removal Overview

A general overview of the biological treatment processes involved in removing nitrogen from wastewater is provided below. The information is an excerpt from the article entitled *Design and Optimization of Two Re-circulating Sand Filter Systems for Nitrogen Removal* by S. Osesek, B.

Shaw, and J. Graham published in the American Society of Agricultural Engineers 7th Onsite Wastewater Treatment Proceedings.

Nitrogen entering a conventional septic system is typically in the organic-N and ammonium-N forms. A properly functioning septic tank will remove approximately 10% of the influent organic nitrogen which is stored in the sludge (Lack et. al., 1981). (MDEQ guidelines for nitrogen removal state that 16.7% of nitrogen is removed from the influent (60ppm-50ppm/60ppm)). In the septic tank, settling and ammonification occur, resulting in effluent containing primarily ammonium-N (USEPA, 1980; Canter and Knox, 1986). One of the most effective means of ammonium removal is through biological nitrification and subsequent denitrification.

Nitrification is commonly defined as the biological oxidation of ammonium to nitrate with nitrite as an intermediate. Autotrophic microorganisms are largely, if not entirely, responsible for nitrification in natural systems. These nitrifying autotrophs require oxygen and derive the carbon for cell synthesis largely from CO_2, carbonates, or bicarbonate (Delwiche, 1981). The overall oxidation of ammonium to nitrate is shown in Eq. (1) (EPA, 1975).

$$NH_4^+ + 2\ O_2 + 2HCO_3^- \rightarrow NO_3^- + H_2CO_3 + H_2O \qquad (1)$$

Equation 1 shows that alkalinity is destroyed by the oxidation of ammonia and that carbon dioxide (H_2CO_3 in the aqueous phase) is produced. Past studies have shown that 6.3 to 7.4 mg of alkalinity are destroyed for every mg of ammonium-N oxidized in attached growth systems (EPA, 1975). Thus, the process of nitrification tends to lower the pH. Almost all nitrifying bacteria have an optimum pH in the alkaline range, usually near 8.0, and only grow slowly at pH values much below neutral (Gaudy & Gaudy, 1980). Eq. (1) also shows that dissolved oxygen is required for the nitrification process. An oxygen requirement of 4.6 mg of O_2 for every mg of ammonium-N oxidized has been theorized to be sufficient for aeration requirements (EPA, 1975). Temperature also plays an important role in the nitrification process. The optimum temperature range for nitrification has been reported as 18 to 35 °C (46.4-95°F) with nitrification ceasing below 5°C (41°F) (Shammas, 1986).

The biological process of denitrification involves the conversion of nitrate-N to primarily nitrogen gas. Denitrification can be accomplished by a relatively broad range of facultative heterotrophic bacteria including *Pseudomonas, Micrococcus, Archromobacter* and *Bacillus* (EPA, 1975). The overall denitrification reaction is shown in Eq. (2) (EPA, 1975).

$$NO_3 + 0.833\ CH_3OH + 0.167\ H_2CO_3 \rightarrow 0.5\ N_2 + 1.33\ H_20 + HCO_3^- \qquad (2)$$

Equation 2 shows that bicarbonate is produced and carbonic acid is reduced whenever nitrate or nitrite is denitrified to nitrogen gas. Experiments have shown that approximately 3.0 mg alkalinity as $CaCO_3$ are produced for every mg of nitrogen reduced. Thus, the tendency of denitrification is to partially reverse the effects of nitrification and raise the pH of the wastewater. The highest rates of denitrification occur within the range of pH 7.0 to 7.5 (EPA, 1975). Eq. (2) shows that an adequate carbon source, CH_3OH (methanol) in Eq. (2), is needed for the

removal rate MDEQ required for level two type treatment systems. The D-Nite was monitored as part of a study conducted by the Montana Water Resources Research Center at Montana State University in Bozeman, MT. Unfortunately, due to several "operational and installation-related mishaps" only one month of representative data was collected (1). Other available data was limited and had mostly been collected by the designing company, so third party confidence was lacking. The design of the system is such that long term maintenance is similar to that of any septic system and can be accomplished by an OWS installer or any person knowledgeable about OWS's.

The cost of the system was comparable to or below that of a raised sand mound which at the time of this study was the level II treatment standard used by MDEQ. Installation of the system could be accomplished by a licensed OWS installer. However, some engineering oversight is necessary to insure the re-circulation pump timer is properly set. A minimum of space in required for installation of this system which allows it to be used for new systems as well as for replacement systems on properties with limited space. This system also appeared to be acceptable to the general public. The entire system is located underground and does not require any special knowledge on the homeowner's part to operate or maintain. The mechanical components are limited to the pumps and control panels similar to many standard pressure dosed septic systems and known to require little maintenance.

1.5.2 Waterloo Nitrex™ Unit

1.5.2.1 System Description

The Waterloo Nitrex™ Unit (Nitrex™), developed by scientists at the University of Waterloo in Ontario, Canada, was a unit designed to passively provide the denitrification step in removing nitrogen from wastewater. The Nitrex™ unit consists of a 1500 gallon concrete septic tank filled with a mixture of sawdust and wood chips. The tank provides an anaerobic environment and the wood chips provide a carbon source to allow denitrification to occur. Prior to the Nitrex™ unit a nitrification step must be provided. For this project an intermittent sand filter (ISF) was chosen to provide nitrification. A system schematic may be found in Appendix A.

For this project, the system consists of a 1000 gallon septic tank, a 500 gallon pump chamber, an 18' x 20' intermittent sand filter, the Nitrex™ unit, a second 500 gallon pump chamber and a drainfield. Raw sewage from the residence enters the 1000 gallon septic tank for primary treatment. The settled septic tank effluent then overflows into the 500 gallon pump chamber. A pump in the pump chamber delivers the effluent to the ISF on a timer controlled dosing schedule. Effluent from the ISF then flows under gravity into the Nitrex™. From the Nitrex™, the effluent enters a second pump chamber (500 gal). When the depth of effluent in the second pump chamber reaches the pumping level, the pump delivers a dose of effluent to the drainfield for final disposal.

A Nitrex™ unit is available for purchase from Septech, Inc.; however, high shipping costs from the factory in Waterloo, Canada make the system cost prohibitive for use in Montana. It was determined that if the system was to be viable in Montana, it would have to be constructed either

onsite or in the vicinity of the site. However, the sawdust and wood chips available in Montana are primarily from soft woods (pine, larch, and fir) and the wood products used in Canada were hardwoods. After some consideration, the designer concluded that the softwood should perform similarly to the hardwood. If the softwood medium was successful, any other systems installed in Montana could be constructed onsite or at a nearby staging area using the softwood products available locally.

An ISF was chosen for the nitrification step prior to the Nitrex™ for two reasons. First, an abundance of data was available indicating that an ISF provided very reliable and complete conversion of ammonia to nitrates. Second, it was an opportunity to monitor an ISF for nitrogen removal. It has been suggested that dosing frequency, dosing volume, hydraulic loading rate and whether or not the effluent is stored beneath the filter all affect the nitrogen removal rate within an ISF. To investigate these suggestions, the ISF was divided in half with each half of the filter operating independently of the other. By dividing the filter in half, both halves could receive the same effluent but at different rates. In addition, one half of the filter was constructed to gravity drain to the Nitrex™ with no ponding of effluent on the bottom of the filter. The other half was constructed to allow either drainage with no ponding or constant effluent ponding in the effluent collection area beneath the filter prior to draining. For this project, the pump dosing the ISF delivered approximately 50 gallons of effluent to the ISF every 180 minutes. This results in 8 doses per 24 hours if 400 gallons of flow is available.

Nitrogen removal rates for the Nitrex™ have been reported as high as 95% on residential waste which equates to total nitrogen concentrations of 1-5 mg/l in the system outflow (2).

1.5.2.2 Selection Criteria Evaluation

The system is designed by Waterloo University and distributed by Septech, Inc., both located in Waterloo, Ontario, Canada. No Nitrex™ system had been installed in Montana prior to this project. Monitoring data from systems installed in areas of Canada with similar climates/conditions to Montana, indicated that this system could meet the 60% nitrogen removal rate MDEQ required for level two type treatment systems. Long term data was not available and the use of softwoods instead of hardwoods in the Nitrex™ tank as the carbon source had not been tested before.

The cost of the Nitrex™ was the highest of the three systems in the study, but was still within the cost range of a raised sand mound. The existing monitoring data showed removal rates much higher than any other systems. Total nitrogen levels less that 5 mg/l leaving the system were standard.

Installation of this system could be accomplished by a licensed OWS installer. The Nitrex™ unit was constructed onsite under the direction of Will Robertson of Waterloo University. It was straight forward and could easily be duplicated onsite with some engineering supervision. It is expected that if MDEQ approves this system in Montana, a Nitrex™ distributor, trained to construct the Nitrex™ unit, would be established in Montana.

One disadvantage to this system, as compared to the other two, is the larger area required for installation. The Nitrex™ itself is the size of a 1500 gallon septic tank, but the ISF requires a minimum of 360 ft^2 of fairly level ground for installation. It was determined that the excellent nitrogen removal rate compensated for the larger area required for installation. This system appeared to be acceptable to the general public. The entire system is located underground and does not require any special knowledge on the homeowner's part to operate or maintain. The mechanical components required for operation are limited to the pumps and control panels similar to any ISF system and are known to require little maintenance. In addition, the Nitrex™ unit utilized sawdust/wood chips that are generally considered a waste product in Montana.

The life of the wood products was/is a possible maintenance concern. The Nitrex™ designers indicated that the life of the Nitrex™ will be in excess of 20 years. If it begins to fail earlier or after 20 years of operation, the wood medium can be replaced at a minimal cost.

1.5.3 NORWECO Singulair Wastewater Treatment Unit Model 960

1.5.3.1 System Description

The NORWECO Singulair Wastewater Treatment Unit Model 960 (Singulair 960) is an extended aeration system. The system is considered a suspended growth type process and is contained within a modified 1500 gallon concrete septic tank. Three separate chambers are partitioned within the tank. The first chamber accepts raw sewage and functions as a settling chamber/septic tank. The effluent from the first chamber flows into the second chamber termed the aeration chamber. In the aeration chamber an aerator blows air into the chamber on an alternating schedule to provide both aerobic and anaerobic conditions within the chamber. The third chamber is a settling/clarification chamber. Installed within the third chamber is a Bio-Static sludge return and a Bio-Kinetic filter system. The Bio-Static sludge return routes settled sludge from the clarification chamber back into the aeration chamber. The Bio-Kinetic filter provides final filtration of the effluent and some equalization of flow. Effluent from the third chamber either flows directly into a drainfield or into a dosing chamber and is pumped to a drainfield for final disposal. The system schematic and general specifications for the Singulair unit may be found in Appendix A.

The original NORWECO extended aeration units were not specifically designed to remove nitrogen. The system treatment focused on the removal of BOD and TSS. However, the company noted that if the aerator was operated periodically, rather than constantly, nitrogen levels in the wastewater were reduced. Theoretically, the effluent is nitrified during the aeration cycles and then it is denitrified during the non-aeration cycles.

Total nitrogen levels at the system outflow for Singulair 960 systems operating in Montana prior to 1998 were reported between 8 and 15 mg/l. This data represents periodic grab samples collected under MDEQ monitoring requirements from several different systems. No incoming flow data or data regarding the consistent operation of the system for nitrogen removal had been collected in Montana.

1.5.3.2 Selection Criteria Evaluation

Several NORWECO systems had been installed in Montana as "experimental" systems when this project began. However, monitoring data was limited for those systems. Information provided by the manufacturer and NSF study data indicated that this system could meet the 60% nitrogen removal rate MDEQ required for level II type treatment systems.

The system is distributed by T.I.G Inc. located in Hamilton, Montana. The cost of the Singulair 960 was comparable to that of a raised sand mound. Installation was accomplished by a licensed OWS installer and setup of the internal components was completed by the T.I.G. technician. The Singulair 960 can be installed in the same space as a standard septic tank. This allows the system to be used for both new development and replacement systems on properties with limited space for wastewater disposal.

The Singulair 960 also seemed acceptable to the general public. The entire system is located underground and does not require any special knowledge for installation or on the homeowners part to operate or maintain. The one disadvantage noted for this system is that the system requires specialized mechanical components and a specially trained technician to install and repair/maintain the system. To offset this disadvantage, the NORWECO distributor in Hamilton requires homeowners to maintain a maintenance agreement providing for two visits per year to maintain the system. The NORWECO company also provides a long term warranty on the aeration unit itself.

1.6 Site Selection

The NORWECO Singulair 960 (Singulair 906) system was installed at an existing residence near Polson, Montana. Occupants of the residence during the study included two adults and three children.

The Nitrex™ was installed at an existing residence near St. Ignatius, Montana. The system replaced an existing system which had failed. The existing septic tank continued to serve as the septic tank for this project. Occupancy of the residence originally included two adults and three children, but it varied throughout the project. Occupants at different times included 1 adult, 1 adult and three children, 2 adults and 3 children and two adults.

The D-Nite System was installed at a new residence. Occupants of the residence during the study included two adults and three children.

All dwellings are the primary residence of the occupants and are occupied 12 months of the year except for short vacation periods.

2. METHODS AND MATERIALS

Monitoring requirements for experimental treatment systems are typically once per quarter or less. This project proposed to monitor 5 consecutive days once a month for 12 to 24 months. This monitoring plan was chosen to provide short term data relating to daily variations (weekend

washing, weekdays, weekends, etc.) as well as long term data relating to the operation of the systems over different seasons and through the biological maturation of the systems.

2.1 Sample Collection and Preservation.

2.1.1 Laboratory Samples

Laboratory samples were collected and placed in 150 ml plastic bottles supplied by the laboratory. Each sample was preserved with sulfuric acid (H_2SO_4) to a pH of 3 and shipped to Montana Environmental Laboratory in Kalispell, Montana for analysis. Plastic self-sealing bailers were used to collect samples. Sampling locations and protocols for each system are specified below.

Norweco Singulair 960

Samples were collected from the settling chamber (septic tank) and the system outlet. All samples were grab type samples. The settling chamber samples were collected directly from the chamber using a 1.5-inch self-sealing bailer. Samples collected from the outlet were obtained from the 4-inch diameter sampling port attached to the outlet piping from September 1999 through July 2000. Sampling port protocol required a minimum of 3 times the volume of the sampling port be purged from the port prior to sample collection. Effluent was purged and samples were collected using a 1.5-inch diameter self-sealing bailer.

The local NORWECO representative had concerns that the sampling port at the outlet could not be purged effectively enough to obtain a representative sample. In July 2000, two outlet samples were retrieved from the system outlet. One sample was collected from within the outlet filter and one from the outlet sampling port. Laboratory analysis results reported a total nitrate plus nitrite of <1 for both samples, TKN of 56.74 for the outlet sample and 53.64 mg/l for the filter sample and an ammonia of 46.16 mg/l for the outlet sample and a concentration of 46.37 mg/l for the filter sample. These results indicate that there is little difference in sample results due to sampling locations. However, to insure the most reliable sampling location was used, all outlet samples beginning with the July 2000 event were retrieved from within the outlet filter. Samples were drawn from the filter using a hose attached to a syringe as per instruction from the NORWECO representative.

Fluidyne D-Nite

The pump chamber/re-circulation tank was the single sampling point for the D-Nite system. All samples were grab type samples and were collected directly from the pump chamber/re-circulation tank using a 1.5-inch diameter self -sealing bailer.

Nitrex™

Three locations were sampled within this system, the pump chamber following the septic tank, the ISF outlets, and the pump chamber following the Nitrex™ outlet. Samples collected from the

pump chambers following the septic tank and the Nitrex™ unit were grab samples and were collected directly from the pump chambers using a 1.5-inch diameter self -sealing bailer.

Samples collected from the ISF were obtained from the sampling ports at the ISF outlet. The samples were composite type samples. Two sampling ports were installed at the ISF outlet, one for each half of the ISF. To provide a representative sample, effluent was collected from each sampling port and an equal volume of each sample was placed into the sample bottle to create a composite sample for analysis. Sampling port protocol required a minimum of 3 times the volume of the sampling port be purged from the ports prior to sample collection. Effluent was purged and samples were collected using a 1.5-inch diameter self-sealing bailer.

2.2 Analytical Methods

2.2.1 Laboratory Analysis

All sample analysis was performed by the Montana Environmental Laboratory in Kalispell, Montana. The analytical methods employed by the laboratory are listed in the below:

Analyte	Method
Total Suspended Solid	EPA method 2540D
Biological Oxygen Demand (BOD)	EPA Method SM5210B
Ammonia (NH_4^+)	EPA Method 350-1
Total Kjeldahl Nitrogen (TKN)	EPA Method 351.2
Nitrate (NO_3^-)	EPA Method 353.2

2.2.2 Field pH and Temperature

In the field, pH and temperature were measured for each sample collected. Measurements were taken using a Cole-Parmer model pH20 pH/mV/Temperature hand held meter. The meter was calibrated prior to each sampling event according to manufacturers instructions. Field analysis data may be found in Appendix B.

3. RESULTS AND DISCUSSION

3.1 System Performance

System performance data is presented and discussed below. All system schematics may be found in Appendix A. All laboratory data may be found in Appendix B. All figures may be found in Appendix C.

3.1.1 Fluidyne D-Nite System

The D-Nite system was sampled for 22 sampling periods between September 1999 and August 2001. Sampling periods were from 1 to 6 days long. A total of 94 samples were collected from this system. All D-Nite samples were collected from the pump chamber/re-circulation tank.

Samples were analyzed for nitrate plus nitrite, ammonia, and total kjeldahl nitrogen (TKN=ammonia+organic nitrogen). The September 1999 sample was analyzed for Biological Oxygen Demand (BOD_5) and Total Suspended Solids (TSS) to establish baseline wastewater strength. Laboratory data is presented in Appendix B.

In late August 1999, construction was completed and the family began living in the residence served by the D-Nite. The system operated from August 1999 through November 1999 prior to the D-Nite re-circulating pump being activated. This allowed two months for septic tank start-up and two months (October and November 1999) to collect background samples from the septic tank effluent. Because the system re-circulates treated effluent back to the front of the septic tank, baseline wastewater characteristic data had to be collected prior to the D-Nite re-circulation pump start-up.

The baseline samples collected in October and November 1999 showed an average nitrate plus nitrite concentration of <1 mg/l, an average TKN of 69.95 mg/l and an average ammonia of 64.3 mg/l. To determine the total nitrogen concentration, the TKN and nitrate/nitrite concentrations are combined. This results in an average total nitrogen at the septic tank outlet of 70.04 mg/l. In October 1999 the BOD measured 246 mg/l and the TSS 110 mg/l. All baseline data was well within expected residential wastewater parameters.

The re-circulation pump was turned on following the November 1999 sampling period. The manufacturer indicated that a one to three month start-up period would be necessary for the D-Nite unit and the septic tank to build the bacterial population necessary to remove nitrogen. Samples collected in December 1999, January 2000 and February 2000 showed the system removing a disappointing 30%, 30% and 19% of total nitrogen from the septic tank effluent respectively. During the February sampling period the re-circulation pump was tested. It was determined that the timer was not set properly and an inadequate amount of effluent was being circulated through the filter. The timer was adjusted and the March 2000 sample showed a 56% removal of total nitrogen from the septic tank effluent. Because the timer was not re-circulating the effluent properly prior to the February 2000 sampling period, actual system start-up is considered to be February 2000 when the timer was adjusted.

MDEQ established the removal of 60% of the total nitrogen entering the septic tank as the definition of a level II type OWS. This percentage is based on a septic tank influent of 60 mg/l and a system effluent of 24 mg/l (1-24/60 = 60% removal). However, total nitrogen concentrations for septic tank influent are difficult to measure accurately but total nitrogen concentrations for septic tank effluent are not. For this study only septic tank effluent concentrations were measured. MDEQ has establish the total nitrogen concentration in septic tank effluent as 50 mg/l. Therefore, the percent removal from septic tank effluent necessary to achieve level II designation is 52% (1-24/50 = 52% removal from septic tank effluent). All calculations throughout this report for percent total nitrogen removal are based on a percent total nitrogen removal from septic tank effluent not septic tank influent.

The D-Nite system performed consistently at the level expected. The total nitrogen removal rates range from 51% (April 2000) to 85% (Aug 2001). The average total nitrogen removal rate for the

entire project, excluding the two month start-up period, was 73%. After April 2000 (second month of D-Nite operation), 52% or more of the total nitrogen entering the system was removed each sampling period. The percent total nitrogen removal was calculated using the average total nitrogen of 70.04 mg/l measured in October and November 1999 prior to system start-up as the septic tank effluent nitrogen concentration (%total nitrogen Removal = (70.04 - system effluent)/70.04)). Figure 1 shows the percent total nitrogen removal rates per sampling period.

Daily sample results for total nitrogen (TKN + nitrates/nitrites) ranged from a high of 36.96 mg/l during April 2000 (month two of operation) to a low of 6.63 mg/l in November 2000 (month 7 of operation). Average total nitrogen ranged from a high of 34.1 mg/l in April 2000 (month 2 of operation) to a low of 11 mg/l in August 2001 (month 16 of operation). After three months of operation, the average total nitrogen concentrations at the system outlet remained below 24 mg/l. The average total nitrogen concentrations per sampling period are presented in Figure 2.

Average TKN concentrations per sampling period ranged from 4.86 to 12.8 mg/l and nitrate/nitrite concentration ranged from 2.81 to 12.63 mg/l. Average ammonia concentration ranged from 0.78 to 8.53 mg/l. Figure 2 presents the average sampling period concentrations for TKN, nitrate/nitrite and ammonia.

A flow meter reading was taken at each sampling event. Because two outside faucets were used for irrigation during the summer months at this residence, the water usage is inflated for the those months. The winter months provide the best estimate of actual water usage in the house. The November through April data suggest that the daily use for this family of five varies from 150 to 300 gallons per day. The average flow can also be calculated using the dose counter for the drainfield. Based on this data the average daily use is 350 gal/day.

Effluent temperature varied as expected with the ambient air temperature. The average effluent temperature for the 22 sampling periods was 14.7 °C. The highest effluent temperature of 32.7 °C occurred in August of 2000 and the lowest effluent temperature of 7.9 °C occurred in February 2001. When effluent temperature is plotted against total nitrogen, a trend showing increased nitrogen removal with increased temperature can be observed. This is expected as most bacterial activity increases with higher temperatures. Effluent temperature and total nitrogen concentrations are presented in Figure 3.

The pH readings taken from the untreated septic tank effluent during the baseline sampling months of October and November 1999, showed an average pH of 8.6 pH units. Once the D-Nite re-circulation pump was operational the average pH dropped to 7.5 pH units. The average pH levels for each sampling period are shown in Figure 3. In general, the nitrification process lowers pH and denitrification partially reverses the effects of nitrification and raises the pH.

One of the purposes of collecting samples on consecutive days was to observe the daily variations in wastewater strength. It was expected that wastewater volume and strength would vary both within the day and from day to day depending upon the activities occurring in the household (weekday, weekend, washdays, etc.). However, little variation in total nitrogen levels was observed between consecutive daily sample results. Figure 4 presents the daily total nitrogen

concentrations. This indicates that the system has a "buffering capacity" capable of compensating for the daily flow/use variations while continuing to produce a consistent nitrogen removal rate.

3.1.2 Waterloo Nitrex®

The Nitrex® system was sampled for 22 sampling periods between September 1999 and August 2001. Sampling periods were 5 days long from October 1999 to August 2000. The sampling frequency was reduced to 1-day per sampling period beginning September 2000 because the system was performing consistently with little daily variation within sampling periods. A total of 198 samples were collected from this system.

The system was put into operation in late June 1999. Sampling began in October 1999 which allowed three months for system start-up. Samples were collected from three areas within the system. One sample was collected from the pump chamber following the septic tank, a second sample was collected from the intermittent sand filter (ISF) outflow, and a third sample was collected from the pump chamber following the Nitrex® unit. Samples were analyzed for nitrate plus nitrite, ammonia, and total kjedahl nitrogen (TKN). One October 1999 sample was also analyzed for BOD and TSS to provide baseline wastewater characteristic data. Laboratory data is presented in Appendix B.

In October 1999, the septic tank effluent BOD measured 106 mg/l and the TSS 34 mg/l, the sand filter effluent BOD measured 186 mg/l and the TSS 6560 mg/l, and the Nitrex™ effluent BOD measured 108 mg/l and the TSS 11mg/l. This baseline data was well within expected residential wastewater parameters except for the sand filter TSS which was above expected levels. It is suspected that this high TSS was due either to incomplete flushing of the sampling port prior to sampling or the fines in the sand media still being flushed through the system. Because the Nitrex™ effluent sample was within acceptable limits additional sampling was not completed.

The average total nitrogen (Total nitrogen =TKN+nitrate/nitrite) concentration in the septic tank effluent was 47.12 mg/l. Average total nitrogen varied from a maximum of 91.62 mg/l in August 2001 to a minimum of 16.75 mg/l in November 2000. The septic tank effluent averaged a nitrate plus nitrite of 0.09 mg/l, a TKN of 47.03 mg/l and an ammonia of 42.9 mg/l. Average septic tank effluent concentrations for TKN, ammonia, and nitrate/nitrite are shown in Figure 5.

The average total nitrogen concentration in the ISF effluent was 31.86 mg/l. Total nitrogen varied from a maximum of 51.04 mg/l in January 2000, to a minimum of 9.31 mg/l in November 2000. Total nitrogen concentrations are shown in Figure 11. During this study, the ISF effluent reported total nitrogen concentrations below 24 mg/l for three sampling periods. The ISF removed an average 31% of the total nitrogen in the septic tank effluent. ISF percent removal per sampling period is shown in Figure 7.

The ISF effluent had an average nitrate plus nitrite of 30.2 mg/l, an average TKN of 1.66 mg/l, and an average ammonia of 0.29 mg/l. The ISF performed as expected and consistently converted 98% of the ammonia in the septic tank effluent to nitrate (nitrification). The remaining

ammonia in the ISF effluent was never greater than 0.5 mg/l. Average ISF effluent concentrations of TKN, ammonia, and nitrate/nitrite for each sampling period are shown on Figure 6.

It has been suggested that the dosing frequency, dosing volume, hydraulic loading rate and whether or not the effluent is stored beneath the filter all affect the nitrogen removal rate within an ISF. To investigate these variables, the ISF was divided in half with each half of the filter operating independently of the other. By dividing the filter in half, both halves could receive the same effluent but on different dosing schedules. In addition, one half of the filter was constructed to gravity drain to the Nitrex™ with no ponding of effluent on the bottom of the filter. The other half was constructed with a valve to allow either drainage with no ponding or constant effluent ponding in the effluent collection area beneath the filter prior to draining.

Investigation of the operation of the ISF was planned for the second year of monitoring. In August 2000, when the alternative dosing and drainage was scheduled to begin, the occupancy of the residence dropped to 1 person. There was inadequate flow to proceed with the alternative dosing/drainage investigation.

The average total nitrogen concentration in the Nitrex™ effluent over all sampling periods was 4.31 mg/l. Total nitrogen average per sampling period varied from a maximum of 18.4 mg/l in January 2001, to a minimum of 1.27 mg/l in June 2001. The corresponding total nitrogen removal was 55% for January 2001 and 97% for June 2001. The Nitrex® removed an average 85% of the total nitrogen entering the unit from the ISF. This equates to an average total nitrogen removal rate for the entire system (ISF+Nitrex™) of 91%. Figure 7 presents the average percent removal per sampling period for the system. The system consistently removed more than the 52% total nitrogen necessary to meet the MDEQ requirement for level II designation.

The Nitrex™ effluent had an average nitrate plus nitrite of 2.32 mg/l, an average TKN of 1.95 mg/l, and an average ammonia of 0.6 mg/l. The average concentrations for each sampling period are presented in Figure 8.

The total nitrogen leaving the Nitrex® increased dramatically in January, February, and April 2001. Four months of effluent temperatures below 7 °C in December, January, February and April of 2001 were measured in the Nitrex™ unit. It is expected that the effluent temperature decrease slowed bacterial activity and reduced the denitrification capability of the system. Once the temperature in the Nitrex® rose above 7 °C total nitrogen leaving the system decreased to previously observed levels. The University of Waterloo experienced this slowdown in denitrification in one of their other systems during winter weather as well (3). Figure 9 presents the total nitrogen leaving the system in relation to the temperature of the effluent. Even though the total nitrogen leaving the system increased in January, February and April 2001, the system continued to meet level II requirements.

A flow meter reading was taken at each sampling event. The outcome was erratic varying from 1.5 gal/day to over 1300 gal/day. The occupancy of the residence did vary anywhere from 1 adult

to 2 adults and 3 children and one outdoor faucet was supplied through the water meter, but these values do not coincide at all with the residents reported usage. It is suspected that the flow meter was not functioning properly. Flow can also be calculated using the dosing counter for the ISF pump. Based on these readings, the average daily flow per sampling period varied from 100 gpd to 500 gpd. The changing occupancy of the residence is reflected in the large variation in the water use.

Effluent temperature decreased as the ambient temperature became cooler and then warmed again as the ambient temperature increased. In general, the wastewater also became cooler as it passed through the system. The highest average effluent temperature of 21.85 °C occurred in August of 2001 at the septic tank pump chamber and the lowest average effluent temperature of 5.3 °C occurred in January 2001 at the Nitrex® outlet. Figure 10 presents the temperature variation of each portion of the system (Septic tank, ISF and Nitrex®) with respect to the sampling month.

The pH readings for the septic tank effluent average 7.0 pH units. The ISF effluent measured an average 6.9 pH units, and the Nitrex™ effluent measured an average 7.26 units. Throughout the monitoring the pH maintained levels appropriate for nitrification and denitrification.

One of the purposes of collecting samples on consecutive days was to observe the daily variations in wastewater strength. It is assumed that wastewater volume and strength can vary from day to day depending upon the activities occurring in the household (weekday, weekend, washdays, etc.). Little variation was noted in total nitrogen concentrations in samples collected on consecutive days during a single sampling event. This indicates that the system has a "buffering capacity" capable of compensating for the daily flow/use variations while continuing to produce a consistent nitrogen removal rate. Figure 11 presents the daily total nitrogen concentrations for the Nitrex™ unit.

3.1.3 NORWECO Model 960

The NORWECO Model 960 system installation was completed in late June 1999. Sampling began the last week in October 2000 which allowed three months for system start-up. Samples were collected from the settling chamber/septic tank and from the system outlet. Eleven sampling periods occurred at this system. Sampling periods varied from 1 to 5 days long. No samples were collected from this system after April 2001 due to poor system performance.

Samples were analyzed for nitrate plus nitrite, ammonia, and total kjeldahl nitrogen (TKN=ammonia+organic nitrogen). One October 1999 sample was analyzed for Biological Oxygen Demand (BOD_5) and Total Suspended Solids (TSS) to establish baseline wastewater strength. Laboratory data is presented in Appendix B.

In October 1999, the septic tank compartment BOD measured 96 mg/l and the TSS 165 mg/l and the system outlet BOD measured 222 mg/l and the TSS 1470 mg/l. This baseline data was well within expected residential wastewater parameters except for the outlet TSS which was above expected levels. It is suspected that this high TSS was due to incomplete flushing of the

sampling port prior to sampling. A sample collected from the aeration chamber in April 2001 reported a BOD of 183 mg/l and TSS for 200 mg/l, both within expected concentrations.

The wastewater characteristics found in the settling tank compartment were comparable to septic tank effluent. The average values were 0.07 mg/l for nitrate/nitrites, 51.6 mg/l for TKN, 41.1 mg/l for ammonia, and 51.6 mg/l for total nitrogen. These values are well within the ranges expected from standard septic tank effluent. Figure 12 presents the average septic tank values.

The concentrations measured at the system outlet averaged 0.07 mg/l for nitrate/nitrites, 67.6 mg/l for TKN, 42.4 mg/l for ammonia, and 62 mg/l for total nitrogen. Outlet analysis results are present in Figure 13. The analysis results of samples collected at the outlet were nearly the same as the inlet samples. This indicates that no nitrogen removal is occurring within the NORWECO Singulair 960. Percent nitrogen removal are charted in Figure 14.

The NORWECO was put into operation in early July 1999. During a routine maintenance visit in October 1999, the NORWECO representative reported that the aeration vent had not been installed properly above the aeration unit. He indicated that the faulty installation did not allow adequate ventilation for proper system operation and replaced the vent. He also indicated that the water softener serving the residence was most likely affecting the system. The softened water itself was not a detriment to the system, but the backflush from the cleaning cycle of the softener was routed to the septic system and was suspected of inhibiting bacterial growth.

Because water softeners are common in Montana homes and this system was likely to be installed as a replacement system for existing homes, it was decided to let the system operate with the water softener online for the next three months. Samples collected in November and December 1999 and January 2000 showed no nitrogen removal. Not only was nitrogen not being removed, but no conversion of ammonia to nitrates (nitrification) was occurring either.

The water softener was taken off-line in January 2000. The system was allowed to operate for the next three months (Jan-March 2000) to see if it could recover from the water softener effects. The March 2000 sample showed no treatment occurring. On April 11, 2000, the entire system was pumped and allowed to naturally refill from the residence. The system was restarted on April 21, 2000. At the end of April, the water-softener backflush reroute to a separate disposal system was completed and the water softener was put back on-line.

The system continued to perform poorly for the next five months through September 2000. In October 2000, the NORWECO representative performed a routine maintenance visit to the site. He reported that the electrical supply to the aerator had been disrupted. It is unknown how long the electricity was off, but during the September 2000 sampling event it was noted in the field log that the aerator was cycling. It is assumed that the electricity was off for less than a month. The system was restarted during the October 2000 routine maintenance visit.

To allow the system to recover, it was operated for the next two months without sampling. A sample collected in December 2000, indicated that the system was still not removing nitrogen.

A NORWECO chemist was consulted in December 2000 regarding the poor performance of the system. He requested that some additional testing be completed. The system was allowed to operate three more months (January, February, & March 2001) before the additional sampling was performed. Results from this sampling event indicated that the system was not reducing nitrogen concentrations. Because sampling for this project was to be competed in August 2001, it was decided that inadequate time remained for troubleshooting this system and it was dropped from any further monitoring.

The reasons behind this system failing to perform are unclear. The aeration mechanism appeared to be operating at each sample collection event, except during the NORWECO technician's site visit in October of 2000 when the breaker had flipped and the electrical supply was cut. The water softener may have been to blame, or it is possible that the water supply or wastewater stream contains some unknown constituent that adversely affected this system. It is also possible that the specific unit supplied for this study was a "lemon". Additional investigation into the cause of system failure was beyond the scope of this study. At no time during this study did the NORWECO Singulair 960 meet the 60% nitrogen removal rate necessary for MDEQ approval as a level II treatment system.

A flow meter reading was taken at each sampling event. The data indicates that the daily use for this family of four is between 150 and 300 gallons per day.

The highest average effluent temperature of 26.2 °C occurred in July of 2000 at the system outlet and the lowest average effluent temperature occurred in December 1999 of 10.5 °C, also at the system outlet. The temperature of samples collected at both the settling tank and the tank outlet was measured. The temperatures at both locations were very similar.

The pH measurements collected from both the septic tank and the system outlet showed an average pH of 7.4 pH units.

3.2 System Cost Comparison

The costs of installing the three systems for this project aren't representative of true installation cost. Each manufacturer provided a portion of the system components at a discount in exchange for access to the monitoring data. In addition all three sites were different and costs varied due to site specifics. To make a more equal comparison, installation cost estimates were developed assuming that the systems were all installed at the same site.

Table 1 shows installation costs for the systems involved in this study. Column one lists the system. Column two reports the actual installation cost incurred for this project. Column three lists an estimated cost if each system were to be installed at the same site. The expenses used to estimate the new installation costs may be found in Appendix D.

Table 1
System Cost Comparison

System	Actual Installation Cost	Estimated New Installation Cost at Same Site ($)
Norweco Singulair	$8573.00	$8,700.00
Waterloo Nitrex™	$12,460.00	$12,350.00
Fluidyne D-Nite	$7,455.00	$7,850.00

Each of the system costs are comparable to the ISF (MDEQ standard for level II treatment) which has an estimated cost of between $8000 and $15, 000. An ISF installation varies due to the variety of drainfields that may follow an ISF, but proximity to an acceptable sand source, excavator cost, and site characteristics all come into play.

4. CONCLUSIONS

The following conclusions are offered regarding the systems studied during this project.

4.1 Fluidyne D-Nite

- The D-Nite system provided 16 consecutive months of nitrogen removal rates at or above the 60% level required for level II treatment designation by MDEQ.
- The maximum total nitrogen leaving the system after the three month start-up period was 23.7 mg/l.
- The average total nitrogen leaving the system after a three-month start-up period was 17.5 mg/l.
- Timer set-up requires engineering oversight to insure proper recirculation ratio.
- Once operational the D-Nite required no maintenance to maintain level II treatment performance levels for the length of the study.

4.2 Nitrex™

- The Nitrex™ system provided 23 consecutive months of nitrogen removal rates at or above the 60% level required for level II treatment designation by MDEQ.

- The maximum total nitrogen leaving the system after a three month start-up period was 18.4 mg/l.
- The average total nitrogen leaving the system after a three-month start-up period was 4.6 mg/l.
- Effluent temperatures below 6°C in the Nitrex™ unit decreases the nitrogen removal capability of the unit.
- Recovery from temperatures in the Nitrex™ below 6°C were observed to be immediate once the temperature was raised above 6°C.
- Once operational the Nitrex™ required no maintenance to maintain level II treatment performance levels for the length of the study.

4.3 NORWECO Singulair 960

- The NORWECO Singulair 960 did not provide a 60% nitrogen removal rate required for level II treatment designation by MDEQ during the course of this study.

4.4 Intermittent Sand Filter (Proceeding Nitrex™)

- The ISF used as the nitrification step with the Nitrex® did not achieve the 60% nitrogen removal rate required for level II treatment designation by MDEQ. It provided a 98% conversion of ammonia to nitrate, but only reached an average nitrogen removal rate of 39%. The results of this study indicate that an ISF will not provide level II treatment when dosed eight times a day with an application rate of approximately 1.2 gal/day/ft^2. Possible sizing and dosing changes may increase the nitrogen removal rates, but those variations were not investigated in this study.

5. RECOMMENDATIONS

5.1 Level II Designation

Based on the monitoring results provided by this study, it is recommended that MDEQ designate both the D-Nite and the Nitrex™ systems as level II type treatment systems for use in Montana.

5.2 System Monitoring and Maintenance

The maintenance necessary to insure that advanced wastewater systems operate properly is a concern. The removal of nitrogen from wastewater is a complicated biological process and some system adjustment and maintenance must be expected. However, once operational, neither the D-Nite system nor the Nitrex™ required maintenance during the course of the study. The NORWECO singulair 960 did not deliver level II treatment levels so system monitoring and maintenance is not addressed.

Both the D-Nite system and the Nitrex™ proved to be maintenance free for the duration of this study. However, the D-Nite system required adjustment of the dosing timer to begin proper operation. To help insure proper system operation, both a short term and a long term monitoring program are proposed for these systems.

5.2.1 Fluidyne D-Nite

After a two month start-up period, the D-Nite system provided nitrogen removal rates from the septic tank effluent greater than the required 52% for the next 16 months. This removal rate is expected to continue. Long term maintenance of the system is expected to consist of replacing the re-circulation pump (20-30 year life).

To insure proper start-up and operation the following guidelines are recommended for the D-Nite system installation:

- Establish a monitoring schedule following installation of the system.

    ⇒ Final Inspection - Insure that the timer is set properly and the re-circulation pump is delivering the designated volume of effluent to the trickling filter.

    ⇒ First Six Months of Operation - Collect a sample in months three and six from the pump chamber/re-circulation tank and analyze it for ammonia and nitrate+nitrite. This monitoring schedule at today's prices cost approximately $70 in laboratory analysis and $100-$200 in sample collection fees. This monitoring insures proper system operation and also allows the re-circulation timer to be adjusted in order to achieve maximum nitrogen removal. Record elapsed pumping time and event counter data at each sampling event.

    ⇒ Years 2 - 20+ - Collect a sample every other year from the pump chamber/re-circulation tank and analyze it for ammonia and nitrate+nitrite to insure the nitrogen removal rates expected are being achieved.

- Require elapsed time meters and event counters on both the re-circulation pump and the drainfield dosing pump. If the monitoring results show poor performance these devices will be helpful in troubleshooting the problems.

5.2.2 Waterloo Nitrex™

After a 3 month start-up period, the Nitrex™ system provided nitrogen removal rates greater than 52% for the next 23 months. This removal rate is expected to continue. However, there is the question of the longevity of the wood chips/sawdust that provide the carbon source for the denitrification step. Calculations performed at Waterloo University indicate that if 20% of the carbon contained in the wood chips was actually available for use, the wood chips/sawdust should last for a minimum of 20 years.

Long term maintenance of the Nitrex™ system is expected to include replacement of the ISF dosing pump (20-30 year life) and possible replacement of the wood products in the Nitrex™ (20-year life?).

To insure proper start-up and operation the following guidelines are recommended for the Nitrex™ system:

- Establish a monitoring schedule following installation of the system.

  ⇒ Final Inspection - Insure that the timer is set properly and the dosing pump is delivering the designated volume of effluent to the ISF.

  ⇒ First Six Months of Operation - Collect a sample in month three and month six from the Nitrex™ outlet and analyze it for ammonia and nitrate+nitrite. This monitoring schedule at today's prices cost approximately $70 in laboratory analysis and $100-$200 in sample collection fees. This monitoring insures proper system operation. Record elapsed pumping time and event counter data at each sampling event.

  ⇒ Years 2 - 20+ - Collect a sample every other year from the Nitrex™ outlet and analyze it for ammonia and nitrate+nitrite to insure the nitrogen removal rates expected are being achieved. This sample should also indicate if and when the wood chips in the Nitrex™ require replacement.

- Require the installation of 4-inch diameter sampling ports at the ISF outlet and the Nitrex™ outlet. This pipe provides areas to collect samples.

- Insure that the ISF is dosed with a timer rather than on a demand schedule.

- Require elapsed time meters and event counters on the ISF dosing pump and the drainfield dosing pump, if one is used. If the monitoring results show poor performance these devices will be helpful in troubleshooting the problems.

It is expected that maintenance issues that may arise for the D-Nite and the Nitrex™ should be fairly easily resolved by a person knowledgeable in OWS maintenance and/or the designing engineer. Both systems are constructed of materials found in ISF's and pressure dosed standard drainfields.

The data provided by this study indicates that the D-Nite and the Nitrex™ are suitable for level II designation under MDEQ regulations. Both systems provided consistent and reliable nitrogen removal while monitored. However, advanced systems are different from the standard OWS used for the last 100 years. The nitrogen removal process is a complicated biological process and can be affected by many outside influences. These same outside influences affect standard OWS, but it has never been a concern because disposal, not treatment, had always been the focus of these systems.

If the purpose of OWS's is changed from wastewater disposal to wastewater treatment then the infrastructure supporting OWS's operation must also change. The path of "out of sight is out of mind" will no longer be acceptable. Neither the D-Nite nor the Nitrex™ required any maintenance during this study to achieve level II nitrogen removal levels or better. However, it is likely that some oversight will always be necessary to insure that these two systems, as well as other OWS's designed to provide a specific level of treatment, are functioning at the level expected.

6. REFERENCES

1. Jones, Warren L., et al. 1998. Performance of Three On-Site Alternative Wastewater Treatment Systems and Their Potential Impact on Groundwater Quality. Department of Civil Engineering, Montana State University, Bozeman, MT.

2. Robertson, Will (University of Waterloo, Canada). Personal interview. February 1999.

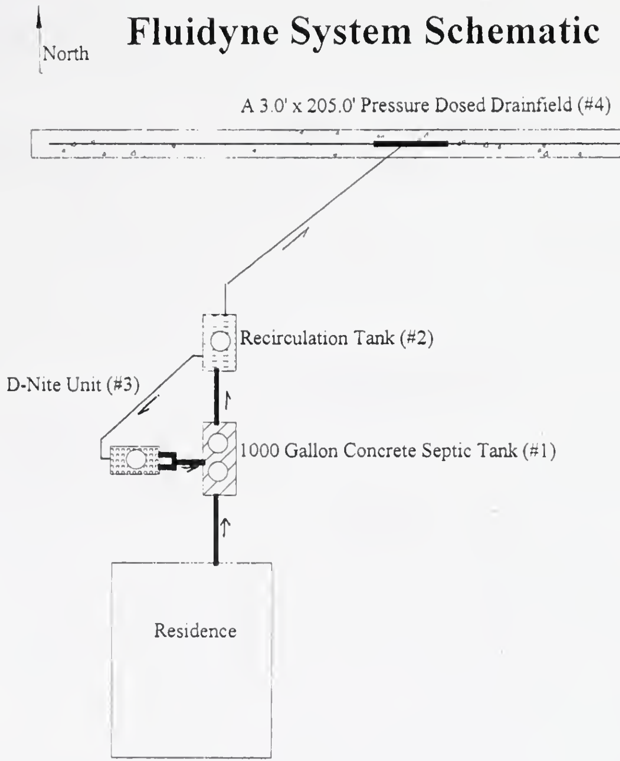
3. Robertson, Will (University of Waterloo, Canada). Personal interview. September 2001.

Note: The CD-ROM included with this report and titled *On-site Wastewater Document Index* contains electronic copies of the majority of the documents collected and reviewed in the course of this study.

Appendix A

System Schematics

Fluidyne System Schematic



Contractor will provide piping:

- Residence to #1 4" sch. 40
- #1 to #2 4" sch. 40
- #2 to #3 2" sch. 40
- #2 to #4 2" sch. 40
- from pumps to tank exterior 2" sch 80 and union, shut off valve, and siphon

Contractors will provide:

#4 - Gravel and Pipe for 3.0' x 205.0' Pressure Dosed Trench

Contractor will excavate and/or install

All Power for Pumps

#1 - 1000 Gallon Concrete Septic Tank

#2 - Recirculation Tank = 1000 Gallon Tank

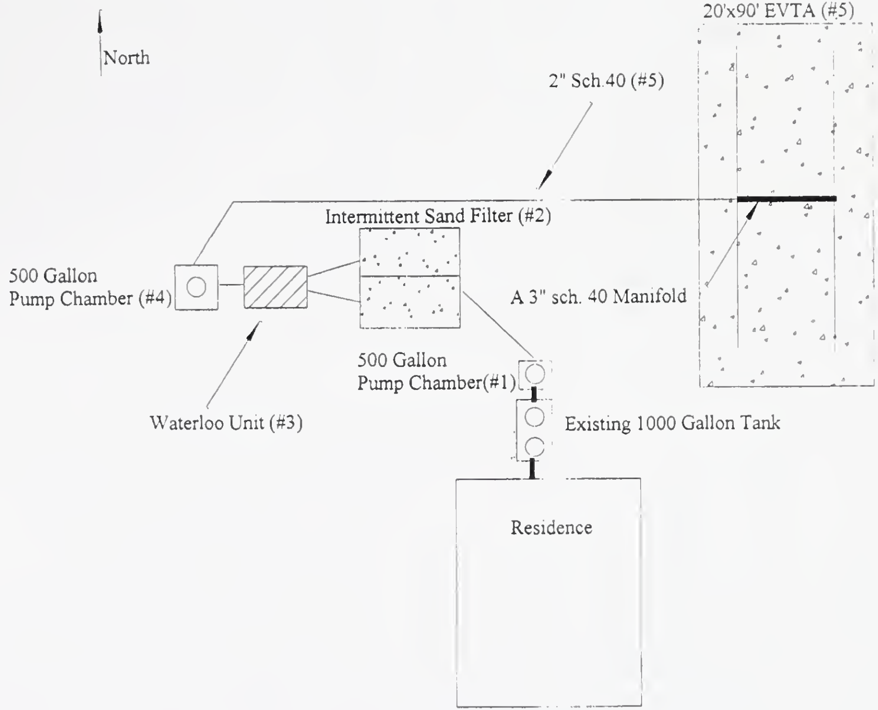
#3 - D-Nite Unit = 1/2 of a 1500 Gallon Tank

#4 - 3.0' x 205.0' Pressure Dosed Drainfield

All Pipe

Pump to drainfield and all interior tank plumbing

Waterloo Unit System Schematic



Contractors will provide.

#1 - 500 Gallon Pump Chamber (no pump)

#2 - Sand and Gravel for Sand Filter

#4 - 500 Gallon Pump Chamber with a 1/2 hp Pump and a screen

#5 - Gravel and Pipe for 20' x 90' EVTA Bed

Contractor will provide piping.

- Existing Tank to #1 4" sch. 40
- #1 to #2 2" sch 40
- #2 to #3 4" sch. 40
- #3 to #4 4" sch. 40
- #4 to #5 2" sch. 40
- from pumps to tank exterior 2" sch 80 union, shut off valve, siphon breaker

Contractors will excavate and/or install:

All Power for Pumps

#1 - 500 Gallon Pump Chamber

#2 - Intermittent Sand Filter – 18' X 20'

#3 - Waterloo Unit

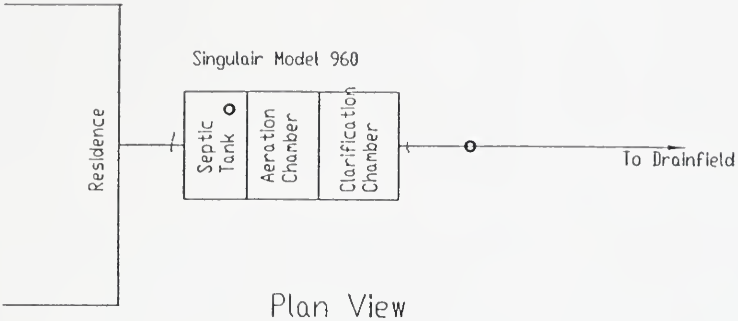
#4 - 500 Gallon Pump Chamber

#5 - 20' x 90' EVTA Bed

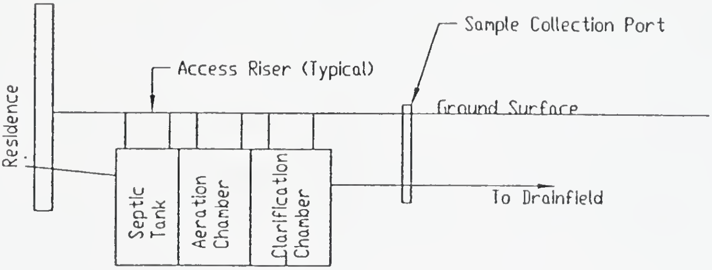
All Pipe

Pump to #2 and Pump to #5 and
'l interior tank plumbing

Singulair Model 960 System Schematic



Plan View



Cross Sectional View

Key

o Sample Collection Point

Scale 1'= 8'

Appendix B

Laboratory Data

Fluidyne

							Nitrate and Nitrite	kjeldahl	Ammonia	Total N
Oct-99	Sample #	Time	pH	Temp	Flowmeter					
09/30/99	Oct-F-001	1420	8.59	19.4	76500		0.06	63.64	54.65	63.70
10/01/99	Oct-F-002	730	8.69	11.8			0.06	58.02	54.97	58.08
10/02/99	Oct-F-003	1640	8.65	15.6	77200		0.06	61.08	56.38	61.14
10/03/99	Oct-F-004	1030	8.72	14.2	77700		0.06	70.00	58.21	70.06
10/04/99	Oct-F-005	1415	8.69	16.1	78300		0.09	69.41	60.56	69.50
			8.668	15.42		Average	**0.07**	**64.43**	**56.95**	64.50
							Nitrate and Nitrite	kjeldahl	Ammonia	
Nov-99										
	Sample #	Time	pH	Temp	Flowmeter					
11/05/99	Nov-F-001	1500	8.66	11	86000		0.09	75.64	69.74	75.73
11/06/99	Nov-F-002	1340	8.64	9.3	86500		0.11	75.40	74.64	75.51
11/07/99	Nov-F-003	1040	8.74	7.3	86600		0.09	80.77	77.30	80.86
11/08/99	Nov-F-004	1520	8.57	9.7	86800		0.11	74.36	68.20	74.47
11/09/99	Nov-F-005	1435	8.52	14.3	87000		0.11	71.18	67.80	71.29
			8.626	10.32		Average	**0.10**	**75.47**	**71.54**	75.57
Dec-99	Sample #	Time	pH	Temp	Flowmeter		Nitrate and Nitrite	kjeldahl	Ammonia	
12/02/99	Dec-F-001	1525	7.79	8.5	92100		0.06	50.20	46.40	50.26
12/03/99	Dec-F-002	940	7.57	7.1	92200		0.07	48.07	46.86	48.14
12/04/99	Dec-F-003	925	7.94	7.4	92300		0.06	45.63	40.19	45.69
12/05/99	Dec-F-004	1200	7.56	8.7	92700		0.06	50.68	46.12	50.74
12/06/99	Dec-F-005	1420			92900		0.06	49.64	47.26	49.70
			7.715	7.925		Average	**0.06**	**48.84**	**45.37**	48.91
Jan-00	Sample #	Time	pH	Temp	Flowmeter		Nitrate and Nitrite	kjeldahl	Ammonia	
02/03/00	Jan-F-001	1415	7.36	10.5	102500		**0.07**	**48.62**	**39.63**	48.69
02/04/00	Jan-F-002	1611	7.46	12.4	102900					
02/05/00	Jan-F-003				103100					0.00
			7.41	11.45						
Feb-00	Sample #	Time	pH	Temp	Flowmeter		Nitrate and Nitrite	kjeldahl	Ammonia	
02/03/00	Feb-F-001	1400	7.55	13	111300		1.28	57.66	44.92	58.94
02/04/00	Feb-F-002		7.66	8	111500		1.41	56.49	44.50	57.90
02/05/00	Feb-F-003	1005	7.62	11.1	111600		0.96	54.83	43.18	55.79
02/06/00	Feb-F-004	1545	7.55	11.7	111800		0.23	54.98	41.55	55.21
02/07/00	Feb-F-005		7.6	11.3	111200		0.08	55.22	40.66	55.30
			7.596	11.02		Average	**0.79**	**55.84**	**42.96**	56.63
Mar-00	Sample #	Time	pH	Temp	Flowmeter		Nitrate and Nitrite	kjeldahl	Ammonia	
03/10/00	Mar-F-001	1512	7.28	13.5	117700		**10.03**	**20.48**	**12.81**	30.51

Apr-00	Sample #	Time	pH	Temp	Flowmeter		Nitrate and Nitrite	kjeldahl	Ammonia	
04/06/00	Apr-F-001	1607	7.33	15.1	124200		22.93	9.92	4.73	32.85
04/07/00	Apr-F-002	1027	7.5	13.9	124500		20.29	12.49	4.56	32.78
04/08/00	Apr-F-003	1922	7.27	15	125600		20.18	16.78	4.81	36.96
04/09/00	Apr-F-004	1740	7.22	15.6	126100		17.73	18.26	6.00	35.99
04/10/00	Apr-F-005		7.28	18.3	126300		15.28	16.66	8.52	31.94
			7.32	15.58		**Average**	**19.28**	**14.82**	**5.72**	34.10
May-00	**Sample #**	**Time**	**pH**	**Temp**	**Flowmeter**		**Nitrate and Nitrite**	**kjeldahl**	**Ammonia**	
05/24/00	May-F-001						**16.02**	**11.49**	**4.85**	27.51
Jun-00	**Sample #**	**Time**	**pH**	**Temp**	**Flowmeter**		**Nitrate and Nitrite**	**kjeldahl**	**Ammonia**	
06/22/00	Jun-F-001	1053	7.68	18.8	206300		**8.99**	**11.48**	**6.81**	20.47
Jul-00	**Sample #**	**Time**	**pH**	**Temp**	**Flowmeter**		**Nitrate and Nitrite**	**kjeldahl**	**Ammonia**	
07/11/00	Jul-F-004		7.3	24.8	241200		4.90	8.76	0.78	13.66
07/12/00	Jul-F-005	1608	7.28	23.5	241900		5.71	8.76	3.87	14.47
						Average	**5.31**	**8.76**	**2.33**	**14.07**
Aug-00	**Sample #**	**Time**	**pH**	**Temp**	**Flowmeter**		**Nitrate and Nitrite**	**kjeldahl**	**Ammonia**	
08/03/00	Aug-F-001		7.4	25.8	301700		3.78	9.98	5.77	13.76
08/04/00	Aug-F-002		7.38	28.7	303600					0.00
08/05/00	Aug-F-003	945	7.43	24.2	305500		2.74	9.15	4.48	11.89
08/06/00	Aug-F-004	1030	7.48	22.8	306700		2.21	10.74	6.11	12.95
08/07/00	Aug-F-005	1546	7.61	25.5	309800		2.52	12.46	8.34	14.98
			7.46	25.4		**Average**	**2.81**	**10.58**	**6.18**	13.40
Sep-01										
	Sample #	**Time**	**pH**	**Temp**	**Flowmeter**		**Nitrate and Nitrite**	**kjeldahl**	**Ammonia**	
09/07/00	Sep-F-001	1244	7.51	14			9.13	7.14	3.38	16.27
09/09/00	Sep-F-003	1505	7.26	20.6	338100		1.78	9.44	3.27	11.22
09/10/00	Sep-F-004	1754	7.47	19.4	339700		2.00	8.87	4.28	10.87
			7.41	18.00		**Average**	**4.30**	**8.48**	**3.64**	12.79
Oct-00	**Sample #**	**Time**	**pH**	**Temp**	**Flowmeter**		**Nitrate and Nitrite**	**kjeldahl**	**Ammonia**	
10/07/00	Oct-F-001	1503	7.41	18.1	349000		10.12	11.41	4.20	21.53
10/08/00	Oct-F-002	1420	7.41	18.5	349200		10.91	12.74	4.74	23.65
10/09/00	Oct-F-003	1438	7.49	13.4	349800		11.74	12.45	4.61	24.19
10/10/00	Oct-F-004	1915	7.35	16.8	349500		10.06	13.07	5.84	23.13
10/11/00	Oct-F-005	1630	7.34	17.3	349700		11.00	12.94	5.39	23.94
			7.40	16.82		**Average**	**10.77**	**12.52**	**4.96**	23.29

Nov-00	Sample #	Time	pH	Temp	Flowmeter		Nitrate and Nitrite	kjeldahl	Ammonia	
11/05/00	Nov-F-001	838	7.37	13	353900		7.50	4.64	2.63	12.14
11/06/00	Nov-F-002	1504	7.44	9.9	354300		5.83	4.63	2.64	10.46
11/07/00	Nov-F-003	1624	7.58	12.6	354500		2.85	3.78	2.07	6.63
11/08/00	Nov-F-004				354700		9.31	6.42	3.80	15.73
11/09/00	Nov-F-005	720	7.31	9.4	354800		6.30	4.82	2.18	11.12
			7.43	11.23		Average	**6.36**	**4.86**	**2.66**	11.22

Dec-00	Sample #	Time	pH	Temp	Flowmeter		Nitrate and Nitrite	kjeldahl	Ammonia	
12/06/00	Dec-F-001		7.34	7.8	360500		10.15	9.95	5.89	20.10
12/07/00	Dec-F-002	2006	7.46	9.9	360700		10.99	10.24	6.09	21.23
12/08/00	Dec-F-003				360900		8.62	7.74	4.61	16.36
12/09/00	Dec-F-004		7.46	9.5	360900		13.31	7.71	5.11	21.02
12/10/00	Dec-F-005		7.5	6.7	361200		12.32	11.04	5.51	23.36
			7.44	8.48		Average	**11.08**	**9.34**	**5.44**	20.41

Jan-01	Sample #	Time	pH	Temp	Flowmeter		Nitrate and Nitrite	kjeldahl	Ammonia	
01/06/01	Jan-F-001	1617	7.82	12.7	365900		12.58	10.45	7.11	23.03
01/07/01	Jan-F-002		7.38	10.1	366200		12.55	11.12	7.22	23.67
01/08/01	Jan-F-003		7.34	8.3	366400		10.64	9.89	6.98	20.53
01/09/01	Jan-F-004		7.34	8.7	366600		10.80	8.93	6.92	19.73
01/10/01	Jan-F-005		7.39	9.8	366700		10.58	9.61	6.23	20.19
			7.45	9.92		Average	**11.43**	**10.00**	**6.89**	21.43

Feb-01	Sample #	Time	pH	Temp	Flowmeter		Nitrate and Nitrite	kjeldahl	Ammonia	
02/10/01	Feb-F-001	729	7.53	5.9	372600		9.36	9.97	6.61	19.33
02/11/01	Feb-F-002	1832	7.45	6.3	372800		7.74	11.98	7.13	19.72
02/12/01	Feb-F-003	1748	7.47	6.2	373000		7.69	10.88	6.74	18.57
02/13/01	Feb-F-004		7.38	7.9	373100		4.18	5.53	4.14	9.71
02/14/01	Feb-F-005		7.61	8.9	373200		8.22	9.46	6.47	17.68
			7.49	7.04		Average	**7.44**	**9.56**	**6.22**	17.00

Apr-01	Sample #	Time	pH	Temp	Flowmeter		Nitrate and Nitrite	kjeldahl	Ammonia	
04/08/01	Apr-F-001	1915	7.63	7.1	383400		10.47	10.82	6.72	21.29
04/09/01	Apr-F-002		7.59	8.7	383700		12.05	10.27	7.22	22.32
04/10/01	Apr-F-003				383000		11.60	11.54	7.62	23.14
04/11/01	Apr-F-004		7.7	7	384000		10.66	11.38	7.48	22.04
04/12/01	Apr-F-005		7.36	9.6	384200		10.52	12.61	7.89	23.13
			7.57	8.10		Average	**11.06**	**11.32**	**7.39**	22.38

May-01	Sample #	Time	pH	Temp	Flowmeter		Nitrate and Nitrite	kjeldahl	Ammonia	
05/13/01	May-F-001	1730	7.49	18.5	390500		11.14	13.01	9.33	24.15
05/14/01	May-F-002	1730	7.64	13.8	390600		11.87	10.83	8.95	22.70
05/15/01	May-F-003	1850	7.74	10.5	390700		13.19	9.93	8.70	23.12
05/16/01	May-F-004	1510	7.77	16.5	391000		13.39	9.07	7.08	22.46
05/17/01	May-F-005	837	7.44	12.2	391100		13.55	8.70	6.30	22.25
							10.34	9.67	7.57	
			7.62	14.30		**Average**	**12.25**	**10.20**	**7.99**	22.45

Jun-01	Sample #	Time	pH	Temp	Flowmeter		Nitrate and Nitrite	kjeldahl	Ammonia	
06/04/01	Jun-F-001		7.75	16.6	398600		8.14	11.59	8.93	19.73
06/05/01	Jun-F-002		7.68	18.7	398700		8.02	10.05	7.95	18.07
06/06/01	Jun-F-003	730	7.57	14.8	399200		8.99	12.28	7.04	21.27
06/07/01	Jun-F-004	1440	7.77	14.8	399500		8.92	10.81	8.36	19.73
	Jun-F_005		7.77	16.1	400200		8.60	11.41	10.37	20.01
			7.71	16.20		**Average**	**8.53**	**11.23**	**8.53**	19.76

Jul-01	Sample #	Time	pH	Temp	Flowmeter		Nitrate and Nitrite	kjeldahl	Ammonia	
07/25/01	Jul-F-001		7.46	26.7	433200		1.98	11.67	7.90	13.65
07/26/01	Jul-F-002		7.63	24.2	433400		3.03	10.38	7.34	13.41
07/27/01	Jul-F-003		7.67	26.5	434600		3.82	10.28	7.03	14.10
07/28/01	Jul-F-004	940	7.67	18.3	436600		4.68	8.26	6.07	12.94
07/29/01	Jul-F-005		7.87	14.9	436700		5.58	12.34	9.32	17.92
			7.66	22.12		**Average**	**3.82**	**10.59**	**7.53**	14.40

Aug-'01A	Sample #	Time	pH	Temp	Flowmeter		Nitrate and Nitrite	kjeldahl	Ammonia	
08/16/01	Aug-F-001	1935	7.63	28.5			2.04	9.06	6.26	11.10
08/17/01	Aug-F-002	1730	7.64	27.8	463100		2.63	10.59	7.18	13.22
08/18/01	Aug-F-003	1530	7.54	32.7	463100		4.11	5.96	4.05	10.07
08/19/01	Aug-F-004	1111	7.67	19.5	463700		4.57	3.78	2.44	8.35
08/20/01	Aug-F-005	2007	7.75	25.2	465000		3.06	5.44	2.62	8.50
			7.646	26.74		**Average**	**3.28**	**6.97**	**4.51**	**10.25**
Aug-'01B										
08/22/01	Aug-F-006	1840	7.74	26	465000		2.70	4.97	2.83	7.67
08/23/01	Aug-F-007	1723	7.81	24.2	465900		1.35	8.53	3.40	9.88
08/24/01	Aug-F-008	1820	7.7	22.2	468500		3.01	9.66	7.42	12.67
08/25/01	Aug-F-009	700	7.68	14.7	468600		3.81	9.47	6.68	13.28
08/26/01	Aug-F-010	1100	7.68	22.1	469900		4.98	10.28	7.39	15.26
08/27/01			7.72	21.84		**Average**	**3.17**	**8.58**	**5.54**	**11.75**

Waterloo

	Sample #	Time	pH	Temp		Nitrate and Nitrite	kjeldahl	Ammonia
Oct-99	**Septic Tank**							
9/30/99	Oct-W-001A	18:00	7.29	18.0		0.11	43.03	39.76
10/1/99	Oct-W-002A	8:00	7.23	12.8		0.09	55.78	38.8
10/2/99	Oct-W-003A	15:30	7.31	17.4		0.08	41.91	39.06
10/3/99	Oct-W-004A	10:45	7.29	16.3		0.07	52.61	41.54
10/4/99	Oct-W-005A	7:00	7.35	13.8		0.08	40.44	33.06
			7.294	15.66	**Average**	0.086	46.754	38.444
	Sandfilter							
	Oct-W-001B		7.20	17.5		11.63	7.33	1.32
	Oct-W-002B		7.26	12.9		17.01	1.16	0.21
	Oct-W-003B		7.30	12.0		6.47	1.64	0.25
	Oct-W-004B		7.21	11.8		17.21	2.48	0.23
	Oct-W-005B		7.19	7.8		16.29	1.44	0.18
			7.232	12.4	**Average**	13.722	2.81	0.438
	Waterloo Unit							
	Oct-W-001D		7.13	18.9		0.05	1.67	0.06
	Oct-W-002D		7.28	10.4		0.06	1.16	0.06
	Oct-W-003D		7.27	15.2		0.04	1.18	0.1
	Oct-W-004D		7.25	14.3		0.06	2.97	0.05
	Oct-W-005D		7.29	11.9		0.05	1.43	0.12
			7.244	14.14	**Average**	0.052	1.682	0.078
Nov-99	**Septic Tank**							
11/5/99	Nov-W-001A	17:05	7.26	10.0		0.11	49.22	46.73
11/6/99	Nov-W-002A	10:55	7.24	12.6		0.09	49.11	45.97
11/7/99	Nov-W-003A	12:10	7.23	11.0		0.12	49.57	46.29
11/8/99	Nov-W-004A	16:15	7.23	11.7		0.12	52.2	48.43
11/9/99	Nov-W-005A	11:40	7.23	15.6		0.11	46.14	43.18
			7.238	12.18	**Average**	0.11	49.248	46.12
	Sandfilter							
	Nov-W-001B	16:45	7.03	8.4		13.98	1.75	0.86
	Nov-W-002B	10:40	7.02	8.7		15.6	2.53	0.78
	Nov-W-003B	11:50	7.09	8.4		13.76	3.39	1.19
	Nov-W-004B	16:00	7.01	8.7		17.84	2.13	1.17
	Nov-W-005B	11:30	6.96	12.8		24.5	2.41	0.73
			7.022	9.4	**Average**	17.136	2.442	0.946
	Waterloo Unit							
	Nov-W-001D	16:50	7.12	8.7		0.09	1.49	0.23
	Nov-W-002D	10:50	7.15	9.6		0.1	1.67	0.21
	Nov-W-003D	12:00	7.15	9.4		0.1	1.85	0.28
	Nov-W-004D	16:10	7.13	10.0		0.09	1.15	0.35
	Nov-W-005D	11:35	7.10	13.3		0.12	1.27	0.27
			7.13	10.2	**Average**	0.1	1.486	0.268
Dec-99	**Septic Tank**							
12/2/99	Dec-W-001A	16:40	6.84	12.2		0.06	53.06	51.97
12/3/99	Dec-W-002A	8:25	7.02	10.2		0.08	51.08	50.01
12/4/99	Dec-W-003A		7.34	10.6		0.07	46.11	43.63
12/5/99	Dec-W-004A	14:46	7.25	9.2		0.08	46.57	44.44
12/6/99	Dec-W-005A					0.07	49.11	47.22
			7.1125	10.55	**Average**	0.072	49.186	47.454
	Sandfilter							
	Dec-W-001B	16:30	6.52	8.6		30.96	5.95	0.46
	Dec-W-002B	8:15	6.56	6.7		35.42	2.63	0.22
	Dec-W-003B		6.95	8.5		37.14	14.45	0.26
	Dec-W-004B	14:26	6.7	7.5		35.84	4.72	0.31
	Dec-W-005B					37.69	2.09	0.24
			6.6825	7.825	**Average**	35.41	5.968	0.298
	Waterloo Unit							
	Dec-W-001D	16:35	6.93	8.8		0.06	1.75	0.46
	Dec-W-002D	8:20	6.93	7.2		0.08	1.74	0.21
	Dec-W-003D		7.33	8.5		0.1	1.88	0.19
	Dec-W-004D	14:36	17.08	8.1		0.08	1.58	0.12
	Dec-W-005D					0.08	1.8	0.15
			9.5675	8.15	**Average**	0.08	1.75	0.226

	Sample #	Time	pH	Temp oC	Flow Meter			Nitrate and Nitrite	kjeldahl	Ammonia
Jan-00	**Septic Tank**									
1/7/00	Jan-W-001A	16:35	7.48	12				0.06	54.34	49.86
1/8/00	Jan-W-002A	15:16	7.44	12.4				0.08	52.36	48.14
1/9/00	Jan-W-003A	9:20	7.01	10.7				0.07	51.85	47.71
1/10/00	Jan-W-004A		7.29	10.8				0.11	51.52	47.94
1/11/00	Jan-W-005A	14.00	7.36	11.8				0.08	51.52	47.74
			7.316	11.54			**Average**	0.08	52.318	48.278
	Sandfilter									
	Jan-W-001B	16:15	6.86	10.6				48.01	1.07	0.1
	Jan-W-002B	15:01	6.68	10.7				49.3	1.17	0.13
	Jan-W-003B	8.45	6.64	10.5				49.78	1.12	0.08
	Jan-W-004B		6.65	10.4				47.99	2.65	0.04
	Jan-W-005B	13.40	6.8	9.7				47.6	1.53	0.1
			6.726	10.38			**Average**	48.536	1.508	0.09
	Waterloo Unit									
	Jan-W-001D	16:25	7.4	10				0.13	1.9	0.27
	Jan-W-002D	15:09	7.86	10.6				0.05	1.63	0.44
	Jan-W-003D	9:00	7.13	9.4				0.09	1.95	0.47
	Jan-W-004D		7.12	9.6				0.09	1.81	0.22
	Jan-W-005D	13:50	7.35	6.5				0.17	2.62	0.12
			7.372	9.22			**Average**	0.106	1.982	0.304
Feb-00	**Septic Tank**									
2/3/00	Feb-W-001A	12:40	7.26	11.2				0.04	56.62	49.93
2/4/00	Feb-W-002A	9:25	7.4	7.9				0.04	59.59	51.38
2/5/00	Feb-W-003A	9:05	7.15	10.9	350			0.04	56.55	51.39
2/6/00	Feb-W-004A	16:56	7.31	12.2	710			0.04	56.39	47.23
2/7/00	Feb-W-005A	16:03	7.24	12.2	860			0.04	55.57	49.84
			7.272	10.88	255		**Average**	0.04	56.944	49.954
	Sandfilter									
	Feb-W-001B	12:18	6.9	11.8				21.69	1.21	0.18
	Feb-W-002B	9:05	6.97	6.3				28.77	0.86	0.73
	Feb-W-003B	8:43	6.72	8.2				33.29	1.29	0.22
	Feb-W-004B	16:42	6.99	10.1				33.41	1.58	0.22
	Feb-W-005B	15:52	6.82	10.9				31.28	0.8	0.66
			6.88	9.46			**Average**	29.688	1.148	0.402
	Waterloo Unit									
	Feb-W-001D	12:27	7.13	8				7.85	1.14	0.33
	Feb-W-002D	9:10	7.25	6				5.62	2.94	1.04
	Feb-W-003D	8:53	6.96	8.2				2.74	2.36	0.28
	Feb-W-004D	16:50	7.28	9.2				1.23	1.8	0.12
	Feb-W-005D	15:56	7.24	9.5				0.58	1.72	0.16
			7.172	8.18			**Average**	3.604	1.992	0.386
Mar-00	**Septic Tank**									
3/10/00	Mar-W-001A	14:08	6.97	13.7	6560			0.07	41.3	38.48
3/11/00	Mar-W-002A		6.95	9.9	6680			0.08	41	39.22
3/12/00	Mar-W-003A	16:45	7.03	12.7	6920			0.08	39.66	39.6
3/13/00	Mar-W-004A	9:50	7.15	12.4	7070			0.04	41	39.88
3/14/00	Mar-W-005A	16:05	7.25	12.2	7180			0.04	42.52	41.02
			7.07	12.18	155		**Average**	0.062	41.096	39.64
	Sandfilter									
	Mar-W-001B	13:45	6.65	10.8				32.19	2.21	0.27
	Mar-W-002B		6.51	8.4				31.85	4.36	0.28
	Mar-W-003B	16:25	6.67	11.2				32.49	0.89	0.23
	Mar-W-004B	9:34	6.57	10.2				32.04	0.76	0.25
	Mar-W-005B	15:47	6.79	11.9				32.36	2.58	0.49
			6.638	10.5			**Average**	32.186	2.16	0.304
	Waterloo Unit									
	Mar-W-001D	13:55	7.04	10.5				0.19	2.16	0.54
	Mar-W-002D		6.97	7				0.09	1.98	0.46
	Mar-W-003D	16:35	7.16	9.4				0.04	1.99	0.5
	Mar-W-004D	9:40	7.03	9.1				0.04	2.11	0.51
	Mar-W-005D	15:55	7.28	9.4				0.04	2.19	0.27
			7.096	9.08			**Average**	0.08	2.086	0.456

	Sample #	Time	pH	Temp oC	Flow Meter (gal)		Nitrate and Nitrite	kjeldahl	Ammonia
Apr-00	**Septic Tank**								
4/6/00	Apr-W-001A	15:08	7.19	12.9	11980		0.04	53.44	44.3
4/7/00	Apr-W-002A	8:33	7.26	10.3	12100		0.04	53.21	43.7
4/8/00	Apr-W-003A	8:18	7.3	13.9	13190		0.04	51.02	42.03
4/9/00	Apr-W-004A	18:54	7.24	16.2	16040		0.04	53.5	43.88
4/10/00	Apr-W-005A	12:05	7.43	17.6	16130		0.04	53.6	43.14
			7.284	14.18	1037.5	Average	0.04	52.954	43.41
	Sandfilter								
	Apr-W-001B	14:54	6.52	12			39.49	1.06	0.23
	Apr-W-002B	8:16	6.51	11.3			43.63	0.61	0.04
	Apr-W-003B	8:08	6.76	12.7			45.59	1.24	0.09
	Apr-W-004B	18:38	6.67	15.6			45.54	2.68	0.34
	Apr-W-005B	11:48	6.69	14.6			43.92	1.43	0.04
			6.63	13.24		Average	43.634	1.404	0.148
	Waterloo Unit								
	Apr-W-001D	15:01	7.05	10.8			0.46	2.33	0.77
	Apr-W-002D	8:25	7.02	8.6			0.04	2.38	0.86
	Apr-W-003D	8:12	7.23	11.1			0.04	2.3	0.88
	Apr-W-004D	18:44	7.15	12.2			0.04	2.34	0.95
	Apr-W-005D	11:54	7.08	14.5			0.2	2.57	0.99
			7.106	11.44		Average	0.156	2.384	0.89
	Septic Tank								
05/13/00	May-W-001A	15:44	6.88	15.8	23620		0.04	51.09	48.15
05/14/00	May-W-002A		6.94	13.6	25240		0.04	49.22	48.02
05/15/00	May-W-003A	15:08	6.99	21	27160		0.04	51.97	48.13
05/16/00	May-W-004A	15:39	6.99	20	27300		0.04	51.1	46.37
05/17/00	May-W-005A	8:09	6.87	13.9	27430		0.04	48.72	47.2
			6.934	16.86	952.5	Average	0.04	50.42	47.574
	Sandfilter								
	May-W-001B	15:24	6.6	14.7			39.43	0.71	0.17
	May-W-002B		6.79	12.6			41.27	1.37	0.2
	May-W-003B	14:53	6.89	19.1			39.92	1.21	0.14
	May-W-004B	15:25	6.88	16.9			39.53	1.21	0.16
	May-W-005B	8:00	6.79	13.5			39.54	0.72	0.16
			6.79	15.36		Average	39.938	1.044	0.166
	Waterloo Unit								
	May-W-001D	15:34	7.01	13.7			0.04	2.42	1.11
	May-W-002D		7.12	11.5			0.04	2.58	1.62
	May-W-003D	14:59	7.23	18.7			0.04	2.86	1.19
	May-W-004D	15:32	7.25	15.7			0.04	2.79	1.27
	May-W-005D	8:05	7.08	11.9			0.04	2.67	1.35
			7.138	14.3		Average	0.04	2.664	1.308
Jun-00	**Septic Tank**								
6/7/00	Jun-W-001A	18:31	6.94	25.8	41470		0.32	47.98	43.3
6/8/00	Jun-W-002A	21:24	6.93	17.4	43060		0.33	43.51	40.34
6/9/00	Jun-W-003A	15:14	7.08	18.6	43150		0.34	44.04	40.26
6/10/00	Jun-W-004A	10:39	7.1	20	43280		0.32	43.72	40.57
6/11/00	Jun-W-005A	10:18	7.07	16	43420		0.31	44.92	41.45
			7.024	19.56	487.5	Average	0.324	44.834	41.184
	Sandfilter								
	Jun-W-001B	18:17	6.8	22.4			30.59	0.88	0.07
	Jun-W-002B	21:15	6.75	17.7			31.01	2.4	2.06
	Jun-W-003B	15:04	6.9	16.2			30.79	0.58	0.04
	Jun-W-004B	10:29	6.92	16.1			30.13	0.49	0.07
	Jun-W-005B	10:09	6.9	13.3			30.31	0.87	0.08
			6.854	17.14		Average	30.566	1.044	0.464
	Waterloo Unit								
	Jun-W-001D	18:24	7.1	22.2			0.28	2.61	0.81
	Jun-W-002D	21:20	7.06	15.9			0.31	3.46	0.85
	Jun-W-003D	15:08	7.17	15.6			0.34	2.54	0.98
	Jun-W-004D	10:33	7.23	17.3			0.29	2.54	0.71
	Jun-W-005D	10:13	7.18	13.2			0.4	2.31	1.15
			7.148	16.84		Average	0.324	2.692	0.9

	Sample #	Time	pH	Temp	Flowmeter gal)		Nitrate and Nitrite	kjeldahl	Ammonia
Jul-00	**Septic Tank**								
7/8/00	Jul-W-001A	8:06	6.94	17.7	58780		0.04	48.88	43.88
7/9/00	Jul-W-002A	8:06	6.96	22	59270		0.04	46.6	41.62
7/10/00	Jul-W-003A	8:40	6.94	20.5	59520		0.04	43.56	39.74
7/11/00	Jul-W-004A	16:36	6.92	24.4	59630		0.04	43.3	38.62
7/12/00	Jul-W-005A	20:11	6.95	22.6	59890		0.04	43.22	37.75
			6.942	21.44	277.5	Average	0.04	45.112	40.322
	Sandfilter								
	Jul-W-001B	7:52	6.76	15.1			20.66	1.16	0.38
	Jul-W-002B	7:51	6.87	21.1			24.52	1.22	0.04
	Jul-W-003B	8:22	6.89	21.2			25.27	1.13	0.74
	Jul-W-004B	16:22	6.9	22.4			24.72	0.88	0.19
	Jul-W-005B	20:01	6.97	22.3			23.77	0.9	0.19
			6.878	20.42		Average	23.788	1.058	0.308
	Waterloo Unit								
	Jul-W-001D	8:00	6.86	15			0.04	2.19	0.68
	Jul-W-002D	7:59	7.04	19.8			0.04	2.1	0.61
	Jul-W-003D	8:27	7.09	19.5			0.04	2.29	0.63
	Jul-W-004D	16:29	7.03	22.9			0.04	2.16	0.7
	Jul-W-005D	20:06	7.14	20.5			0.04	2.89	0.54
			7.032	19.54		Average	0.04	2.36	0.62
Aug-00	**Septic Tank**								
8/3/00	Aug-W-001A	17:28	6.84	23.4	72600		0.04	32.34	29.76
8/4/00	Aug-W-002A	16:25	6.88	26.5	73750		0.04	32.98	30.26
8/5/00	Aug-W-003A	11:12	6.96	23.5	76670		0.04	29.76	29.26
8/6/00	Aug-W-004A	8:45	6.91	18.6			0.04	30.34	28.92
8/7/00	Aug-W-005A	16:50	6.81	22.9	78830				
			6.88	22.98	1557.5	Average	0.04	31.355	29.55
	Sandfilter								
	Aug-W-001B	17:17	6.97	21.8			27.56	3.07	0.19
	Aug-W-002B	16:08	7.16	24.1			29.27	2.67	0.3
	Aug-W-003B	11:01	7.15	22.5			25.44	2.01	0.32
	Aug-W-004B	8:32	7.16	17.2			25.01	2.58	0.09
	Aug-W-005B	16:35	6.98	23.2					
			7.084	21.76		Average	26.82	2.5825	0.225
	Waterloo Unit								
	Aug-W-001D	17:25	7.36	20.8			0.04	2.28	1.04
	Aug-W-002D	16:14	7.32	23.5			0.04	2.41	0.93
	Aug-W-003D	11:06	7.49	20.4			0.04	2.36	0.99
	Aug-W-004D	8:36	7.36	16.8					
	Aug-W-005D	16:40	7.21	21.2					
			7.348	20.54		Average	0.04	2.35	0.99
Sep-00	**Septic Tank**								
9/10/00	Sep-W-002A	9:15	7.12	15.1	80380.0		0.04	26.32	24.64
					45.6				
	Sandfilter								
	Sep-W-002B	9:07	7.13	12.6			11.44	1.28	0.2
	Waterloo Unit								
	Sep-W-002D	9:09	7.02	14.1			0.04	4.09	2.29

	Sample #	Time	pH	Temp	Flowmeter gal)		Nitrate and Nitrite	kjeldahl	Ammonia
Oct-00	**Septic Tank**								
10/8/00	Oct-W-002A	17:28	6.84	23.4	82750		0.04	35.8	31.96
					84 6428571				
	Sandfilter								
	Oct-W-002B	17:17	6.97	21.8			22.51	1 91	0.14
	Waterloo Unit								
	Oct-W-002D	17:25	7.36	20.8			0.04	2.5	0.76
Nov-00	**Septic Tank**								
11/4/00	Nov-W-002A	16:13	7.28	7.3	83480		0.04	16.71	14.96
					27.037037				
	Sandfilter								
	Nov-W-002B	16:03	7.17	7			8.89	0.42	0.04
	Waterloo Unit								
	Nov-W-002D	16:07	7.27	7.6			0.04	2	0.1
Dec-00	**Septic Tank**								
12/9/00	Dec-W-004A	11.00	6.9	7.3	83540		0.68	32.97	28.81
					1.71428571				
	Sandfilter								
	Nov-W-004B	10:48	6.75	5.4			29.34	0.53	0.34
	Waterloo Unit								
	Nov-W-004D	10:54	7.07	6.1			1.82	0.61	0.6
Jan-01	**Septic Tank**								
01/07/01	Jan-W-001A		7	7	83580		0.04	40.93	36.96
					1.37931034				
	Sandfilter								
	Jan-W-001B	14.08	6.69	5.4			39.81	2.28	0.27
	Waterloo Unit								
	Jan-W001D	14:13	7.06	5.3			17.67	0.75	0.35
Feb-01	**Septic Tank**								
02/11/01	Feb-W-002A	16:45	7.02	8.1	83620		0.04	62.14	58.24
					1.14285714				
	Sandfilter								
	Feb-W-002B	16:30	6.71	10.8			46.7	0.22	0.04
	Waterloo Unit								
	Feb-W002D	16:40	7.18	7.0			15.87	0.22	0.07
Apr-01	**Septic Tank**								
04/08/01	Apr-W-002A		7.31	8.2	83650		0.04	54.11	52.82
					0.53571429				
	Sandfilter								
	Apr-W-002B	18:03	7.1	6.1			19.3	1.53	0.56
	Waterloo Unit								
	Apr-W002D		7.31	6.2			10.16	2.46	1.12

	Sample #	Time	pH	Temp	Flowmeter			Nitrate and Nitrite	kjeldahl	Ammonia
May-01										
05/13/01	May-W-001A		7.15	15.5	83650			0.04	50.63	48.82
					0					
	Sandfilter									
	May-W-001B		7.12	13.6				45.93	0.82	0.34
	Waterloo Unit									
	May-W-001D		7.29	12.8				1.36	1.64	0.48
Jun-01	**Septic Tank**									
06/10/01	Jun-W-001A	15:50	6.99	14.9	83700			0.04	46.83	42.84
					1.78571429					
	Sandfilter									
	Jun-W-001B		7.08	13.5				31.45	0.8	0.23
	Waterloo Unit									
	Jun-W-001D		7.06	13.0				0.04	1.23	0.07
Jul-01	**Septic Tank**									
07/28/01	Jul-W-004A	11:43	6.99	20.6	83800			0.07	58.7	54.71
					2.08333333					
	Sandfilter									
	Jul-W-004B		6.89	19.4				27.16	2.31	0.37
	Waterloo Unit									
	Jul-W-004D		7.12	20.5				0.04	2.35	0.12
Aug-'01	**Septic Tank**									
08/18/01	Aug-W-003A		6.86	27.9	84170			0.04	44.28	40.46
	Aug-W-010A	9.58	6.94	20.6	84200			0.04	47.3	46.51
					4.28571429		**Average**	0.04	91.58	86.97
	Sandfilter									
	Aug-W-003B		7.07	23.8				35.27	1.52	0.3
	Aug-W-010B		6.92	17.7				45.9	1.07	0.21
							Average	40.585	1.295	0.255
	Waterloo Unit									
	Aug-W-003D		6.73	26.6				0.04	1.47	0.29
	Aug-W-010D		6.67	17.1				0.05	1.97	0.45
							Average	0.045	1.72	0.37

NORWECO

	Sample #	Time	pH	Temp	V		Nitrate	kjeldahl	Ammonia
			7.23	15.2		Average	14.32	4.245	0.6705
Oct-99	**Settling Chamber**								
9/30/99	Oct-N-001A		7.13	18.9			0.08	54.06	42.92
10/1/99	Oct-N-002A		7.28	10.4			0.09	55.16	35.99
10/2/99	Oct-N-003A		7.27	15.2			0.11	47.5	37.88
10/3/99	Oct-N-004A		7.25	14.3			0.09	44.14	33.1
10/4/99	Oct-N-005A		7.29	11.9			0.1	46.75	37.29
			7.244	14.14		Average	0.094	49.522	37.436
	Outlet								
	Oct-N-001B		7.13	18.9			0.12	127.64	42.48
	Oct-N-002B		7.28	10.4			0.12	53.39	40.85
	Oct-N-002B		7.27	15.2			0.13	68.8	38.96
	Oct-N-003B		7.25	14.3			0.12	49.65	36.74
	Oct-N-004B		7.29	11.9			0.13	71.12	35.58
			7.244	14.14		Average	0.124	74.12	38.922
Nov-99	**Septic Tank**								
11/5/99	Nov-N-001A	17:05	7.26	10.0		13	0.18	50.51	36.02
11/6/99	Nov-N-002A	10:55	7.24	12.6		13	0.17	47.56	37.95
11/7/99	Nov-N-003A	12:10	7.23	11.0		13	0.14	48.99	34.88
11/8/99	Nov-N-004A	16:15	7.23	11.7		13	0.14	44.51	34.55
11/9/99	Nov-N-005A	11:40	7.23	15.6		13	0.14	46.61	35.38
			7.238	12.18		Average	0.154	47.636	35.756
	Outlet								
	Nov-W-001B	16:45	7.03	8.4			0.2	81.81	38.24
	Nov-W-002B	10:40	7.02	8.7			0.14	48.75	34.72
	Nov-W-003B	11:50	7.09	8.4			0.14	43.92	34.59
	Nov-W-004B	16:00	7.01	8.7			0.16	46.88	34.48
	Nov-W-005B	11:30	6.96	12.8			0.14	49.01	34.7
			7.022	9.4		Average	0.156	54.074	35.346
Dec-99	**Septic Tank**								
12/2/99	Dec-W-001A	16:40	6.84	12.2		13	0.08	44.74	34.99
12/3/99	Dec-W-002A	8:25	7.02	10.2		13	0.09	46.32	36.6
12/4/99	Dec-W-003A		7.34	10.6		13	0.1	45.95	37.85
12/5/99	Dec-W-004A	14:46	7.25	9.2		13	0.08	45.29	35.37
12/6/99	Dec-W-005A					13	0.08	45.38	34.51
			7.1125	10.55		Average	0.086	45.536	35.864
	Outlet								
	Dec-W-001B	16:30	6.52	8.6			0.11	61.62	36.67
	Dec-W-002B	8:15	6.56	6.7			0.07	38.04	35.18
	Dec-W-003B		6.95	8.5			0.1	45.44	39.11
	Dec-W-004B	14:26	6.7	7.5			0.1	41.84	35.11
	Dec-W-005B						0.09	46.38	33.92
			6.6825	7.825		Average	0.094	46.664	35.998
	Sample #	**Time**	**pH**	**Temp**	**V**				
Jan-00	**Septic Tank**								
1/7/00	Jan-W-001A	16:35	7.48	12			0.15	68.11	51.93
	Outlet								
	Jan-W-001B	16:15	6.86	10.6			0.15	101.4	52.38

	Sample #	Time	pH	Temp	Flowmeter (gal)		Nitrate and Nitrite	kjeldahl	Ammonia
Feb-00	**Septic Tank**								
2/3/00	Feb-W-001A	12:40	7.26	11.2			0.06	63.44	48.31
	Outlet								
	Feb-W-001B	12:18	6.9	11.8			0.08	75.57	48.05
Mar-00	**Septic Tank**								
3/14/00	Mar-W-001A	14:08	6.97	13.7	6560		0.04	51.25	36.63
	Outlet								
	Mar-W-001B	13:45	6.65	10.8			0.04	133.5	41.23
Apr-00	**Septic Tank**								
4/7/00	Apr-W-001A	15:08	7.19	12.9	11980				
	Outlet								
	Apr-W-001B	14:54	6.52	12					
1-May-00	**Septic Tank**								
5/17/00	May-W-001A	15:44	6.88	15.8	23620		0.04	52.18	47.38
	Outlet								
	May-W-001B	15:24	6.6	14.7			0.04	61.73	46.87
Jun-00	**Septic Tank**								
6/7/00	Jun-W-001A	18:31	6.94	25.8	41470				
	Outlet								
	Jun-W-001B	18:17	6.8	22.4					
Jul-00	**Septic Tank**								
7/11/00	Jul-W-001A	8:06	6.94	17.7	58780		0.04	30.57	23.28
	Outlet								
	Jul-W-001B	7:52	6.76	15.1			0.07	47.54	40.66
Aug-00	**Septic Tank**								
8/3/00	Aug-W-001A	17:28	6.84	23.4	72600		0.04	46.74	33.17
	Outlet								
	Aug-W-001B	17:17	6.97	21.8			0.04	48.99	36.26
Sep-00	**Septic Tank**								
9/10/00	Sep-W-002A	9:15	7.12	15.1	80380.0				
	Outlet								
	Sep-W-002B	9:07	7.13	12.6					

	Sample #	Time	pH	Temp	Flowmeter (gal)		Nitrate and Nitrite	kjeldahl	Ammonia
Oct-00	**Septic Tank**								
10/7/00	Oct-W-002A	17:28	6.84	23.4	72600				
	Outlet								
	Oct-W-002B	17:17	6.97	21.8					
Nov-00	**Septic Tank**								
11/6/00	Nov-W-002A	16:13	7.28	7.3	83480				
	Outlet								
	Nov-W-002B	16:03	7.17	7					
Dec-00	**Septic Tank**								
12/6/00	Dec-W-004A	11:00	6.9	7.3	83540		0.04	60.97	61.19
	Sandfilter								
	Nov-W-004B	10:48	6.75	5.4			0.04	50.26	53.4
Jan-01	**Septic Tank**								
1/6/01	Jan-W-001A		7	7	83580				
	Outlet								
	Jan-W-001B	14:08	6.69	5.4					
Feb-01	**Septic Tank**								
2/11/00	Feb-W-002A	16:45	7.02	8.1	83620				
	Outlet								
	Feb-W-002B	16:30	6.71	10.8					
Apr-01	**Septic Tank**								
5/13/01	Apr-W-002A		7.31	8.2	83650				
	Outlet								
	Apr-W-002B	18:03	7.1	6.1			0.04	49.54	37.18

BOD and TSS Laboratory Results

System	Date	Sampling Location	BOD mg/l	TSS mg/l
D-Nite	9/30/99	Recirc Tank	246	110
Nitrex	9/30/99	ISF pump chamber	106	34
		ISF outlet	186	6560
		Nitrex outlet	108	11
Norweco	9/30/99	Settling chamber	96	165
		System outlet	222	1470
	4/17/01	Aeration chamber	183	200

Appendix C

Figures 1-14

Figure 1

Fluidyne - Percent Reduction in Total Nitrogen

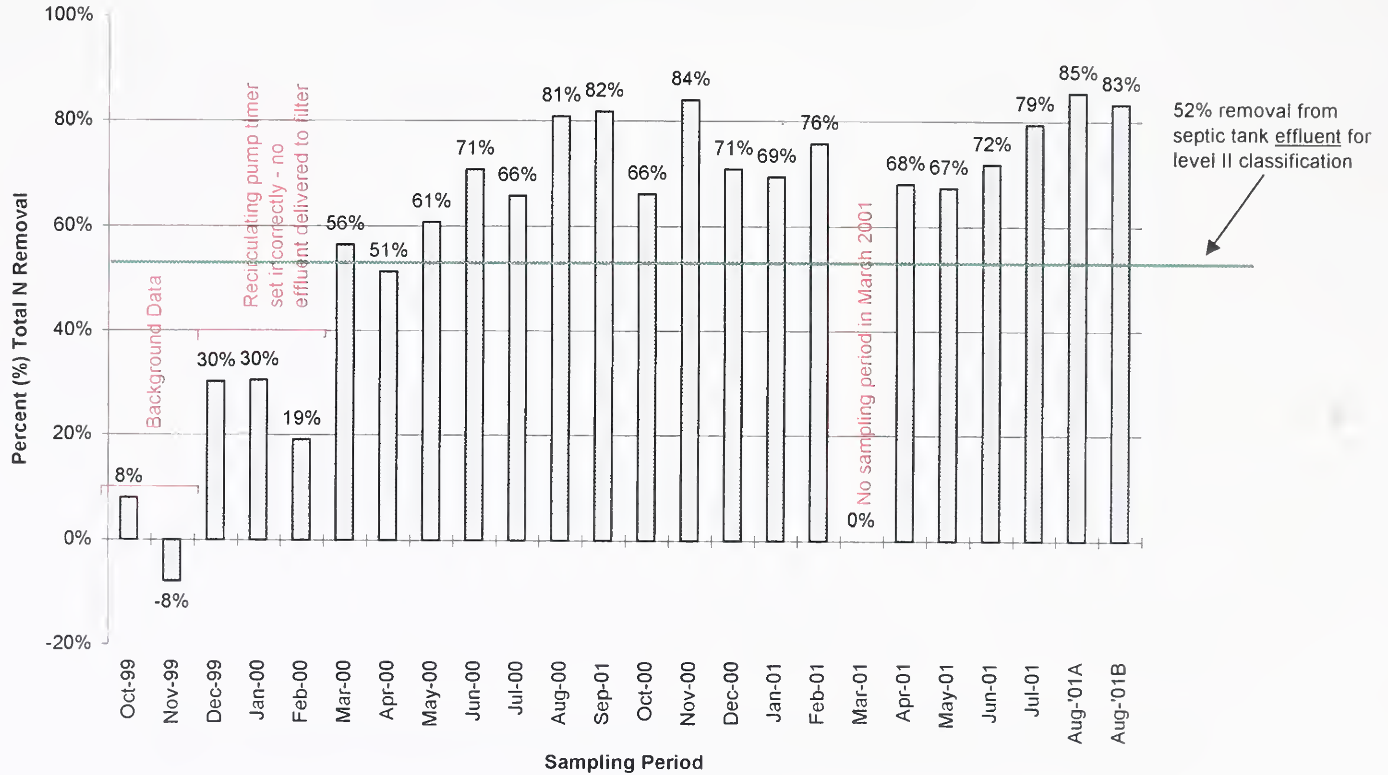


Figure 2
Fluidyne - Sampling Period Average Concentrations

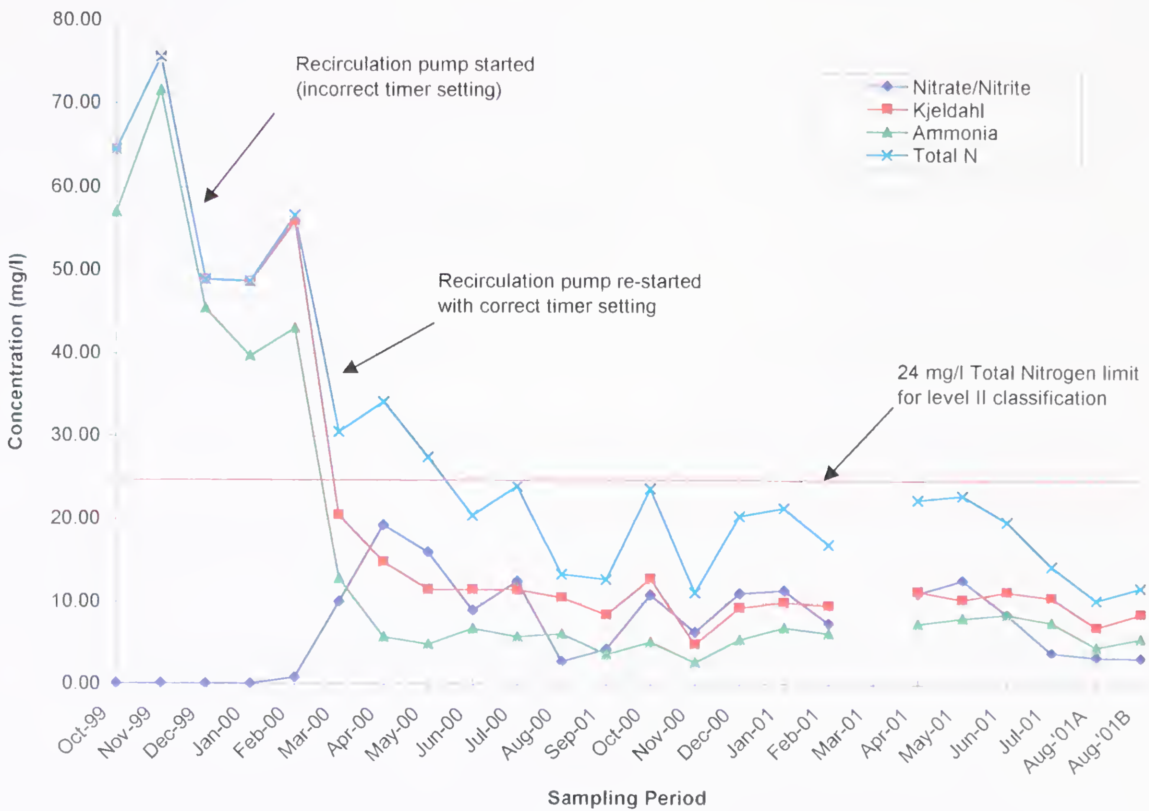


Figure 3
Fluidyne - Average Total N vs Temp & pH

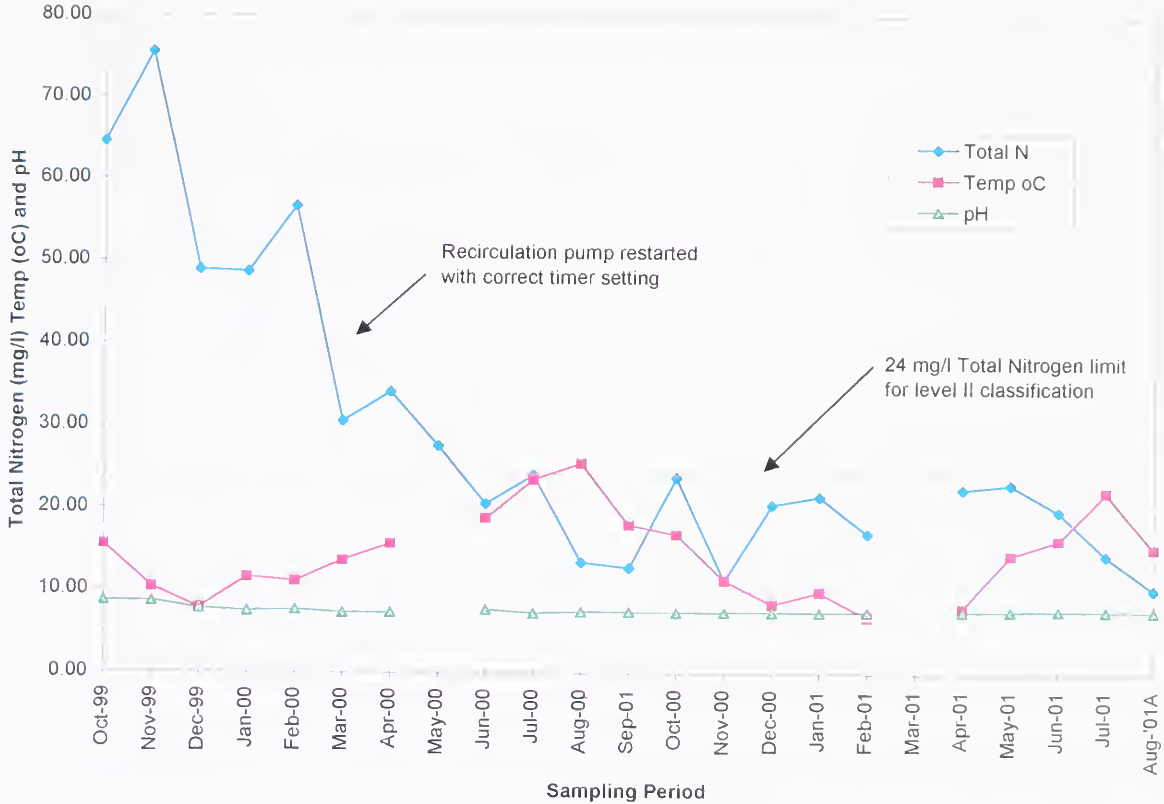


Figure 4
Fluidyne - Total Nitrogen Daily Values

Figure 5

Waterloo - Septic Tank Average Concentrations

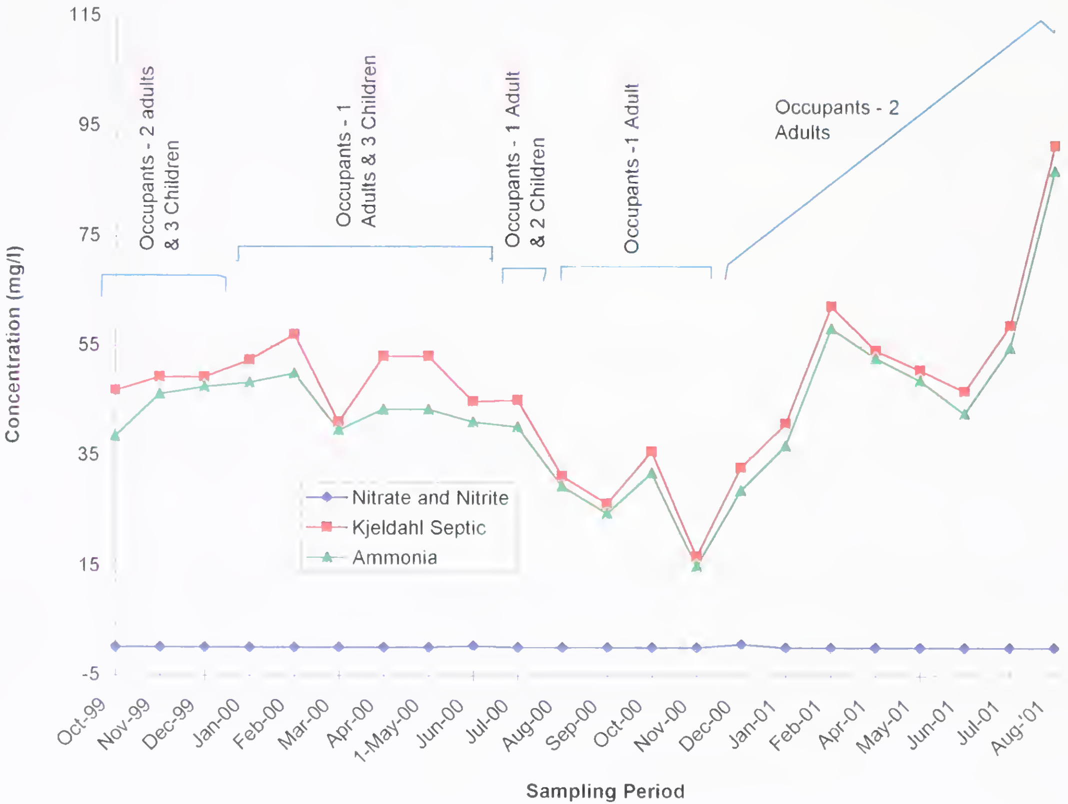


Figure 6
Waterloo - ISF Average Concentrations

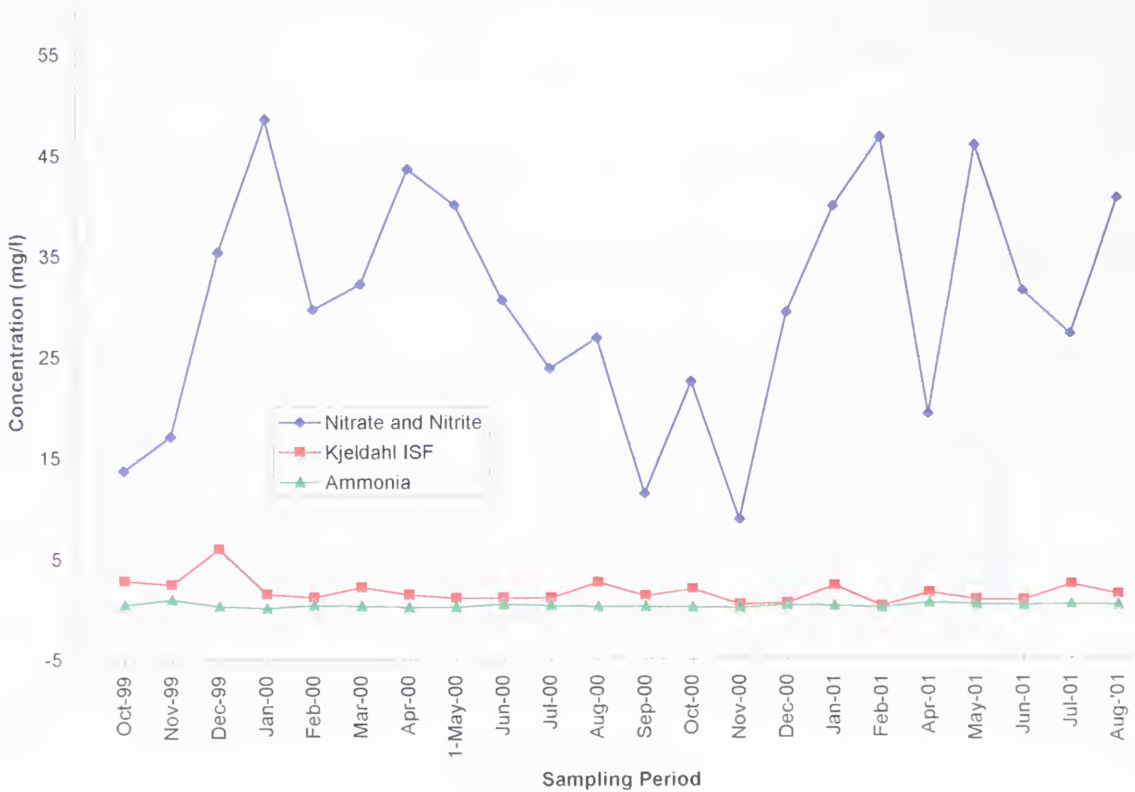


Figure 7
Waterloo ISF and Nitrex Percent Total Nitrogen Removal

Figure 8

Waterloo - Nitrex Average Concentrations

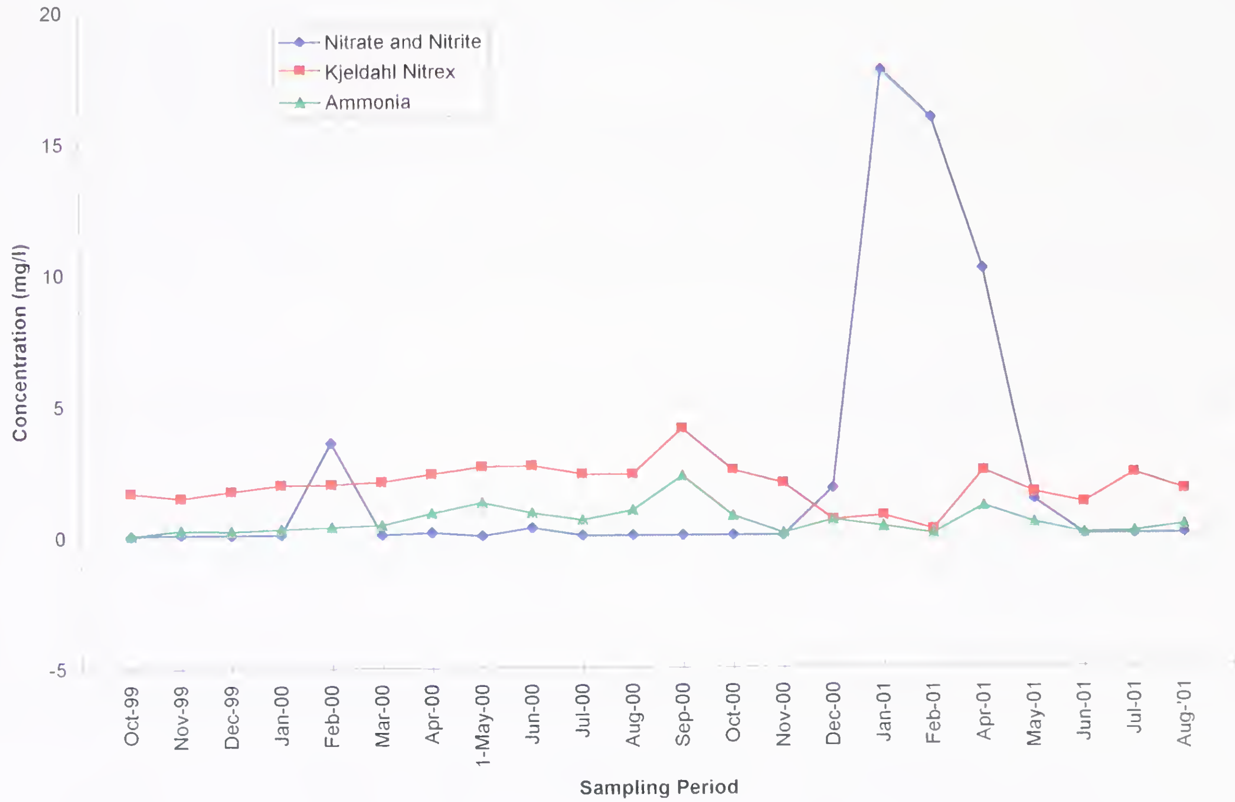


Figure 9
Waterloo Nitrex Unit - Temp vs Total N Concetnration

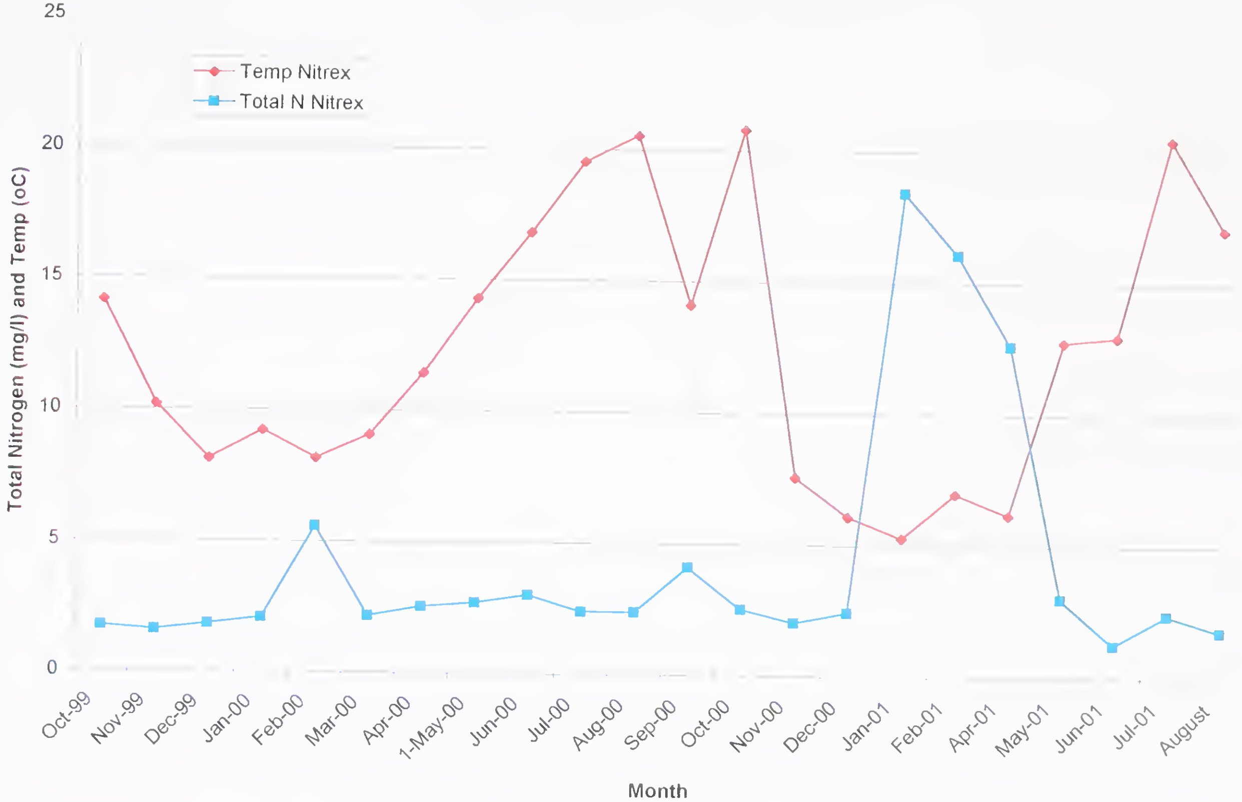


Figure 10
Waterloo - System Temperatures

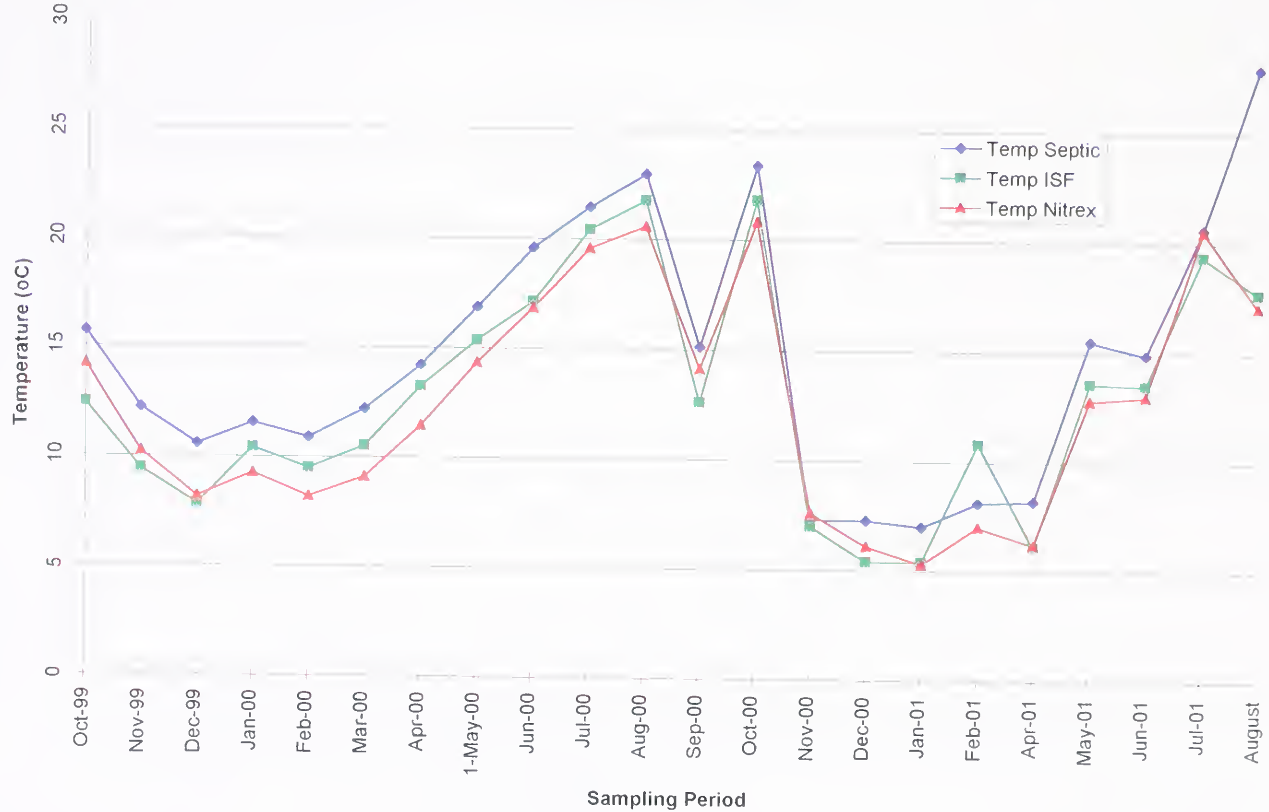


Figure 11
Waterloo - Total Nitrogen

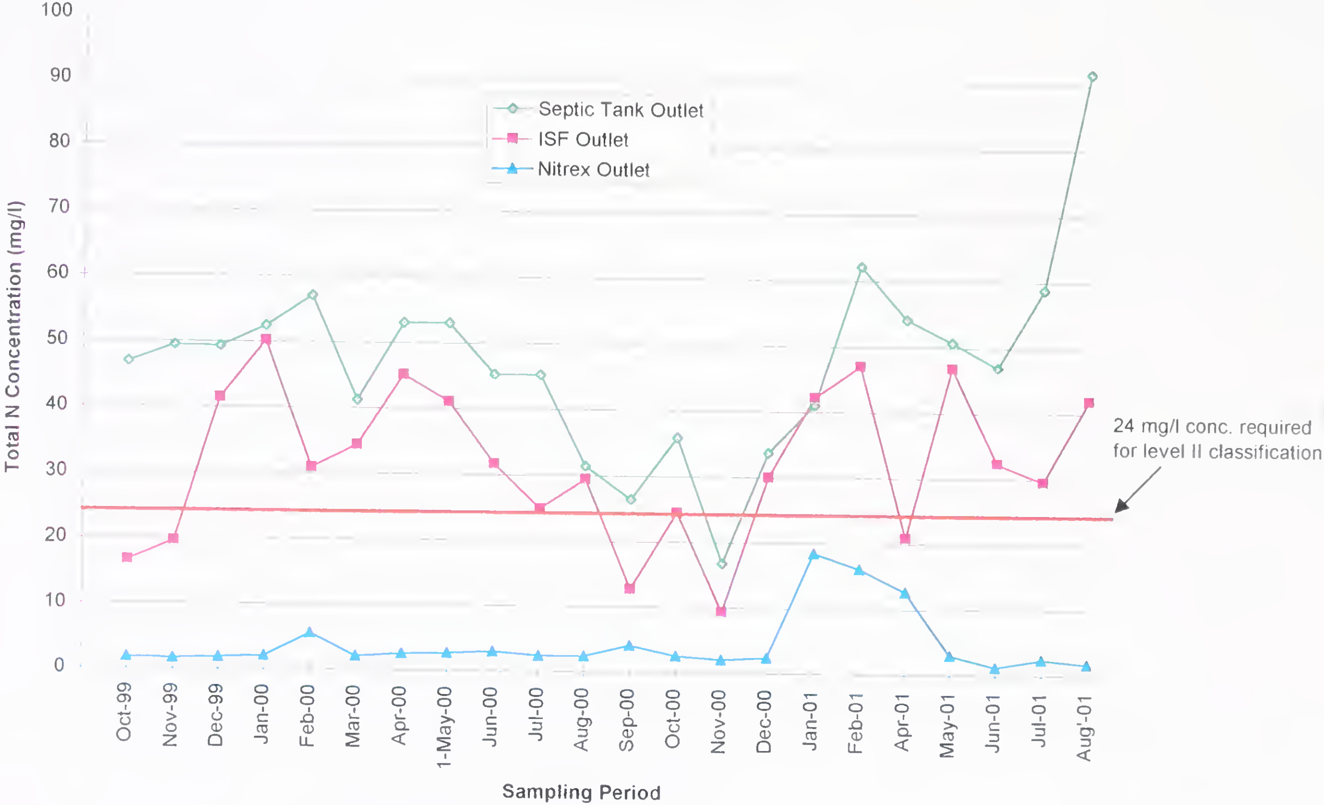


Figure 12
Norweco-Septic Tank

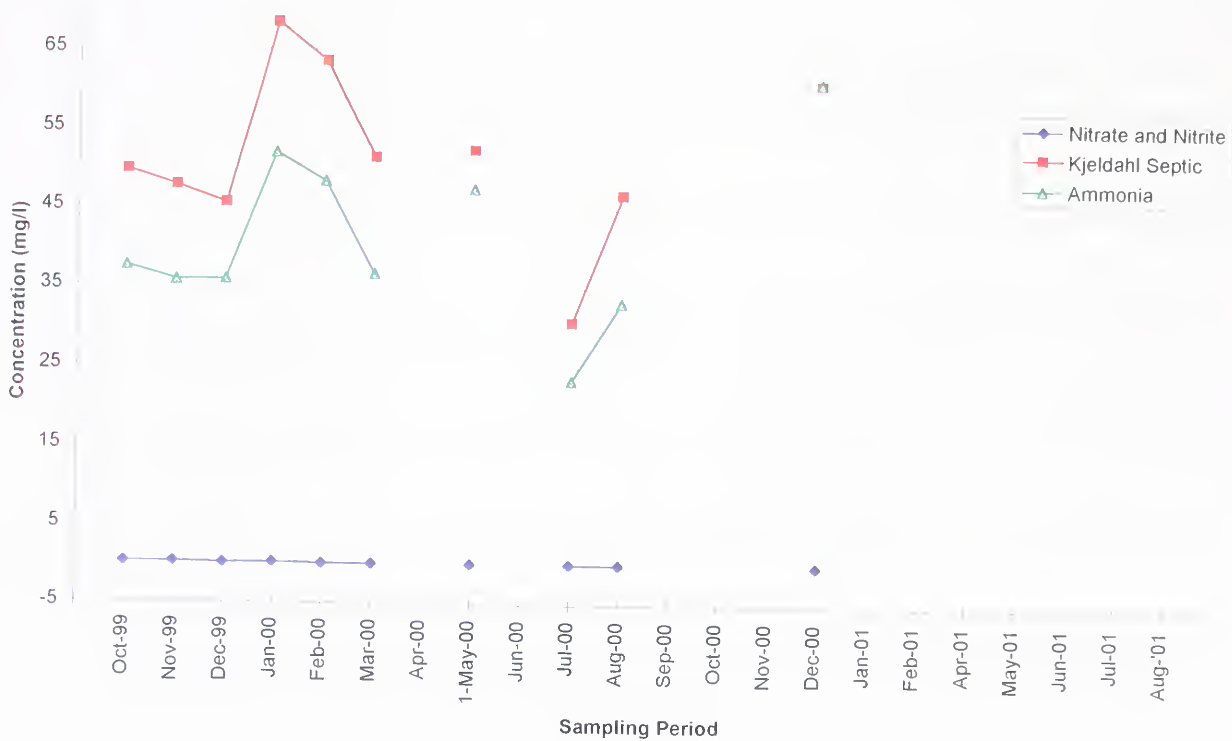


Figure 13
Norweco - System Outlet

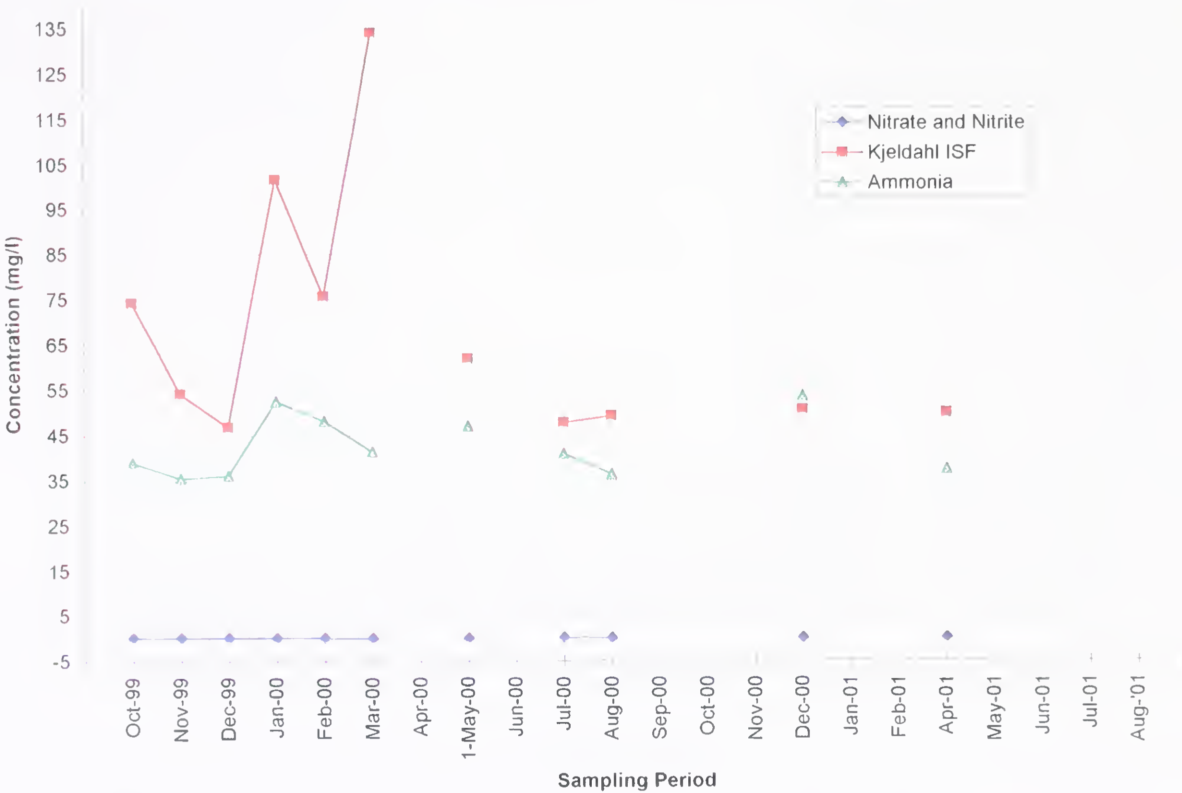
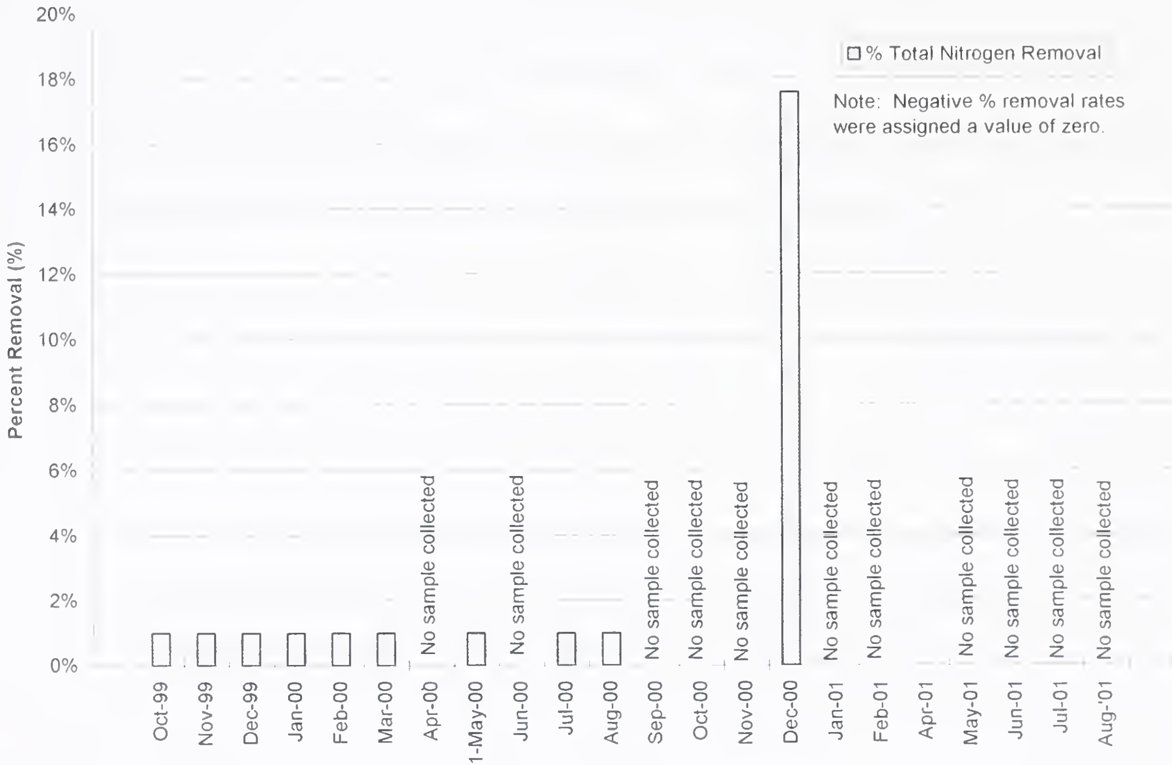


Figure 14
Norweco - Percent Total Nitrogen Removal



Appendix D

Installation Cost Calculations

System Cost Comparison Calculations

D-Nite

Standard OWS (septic tank and drainfield)	$4,500.00
Fluidyne D-Nite Components	$3,000.00
Additional Installation	$350.00
Total Cost	$7,850.00

Nitrex

Standard OWS (septic tank and drainfield)	$4,500.00
Sand Filter (components and install)	$6,000.00
Nitrex Components	$1,500.00
Additional Installation	$350.00
Total Cost	$12,350.00

Norweco

Standard OWS (septic tank and drainfield)	$4,500.00
Norweco Model 960 Components	$4,200.00
Additional Installation	$500.00
Septic Tank Credit	-$500.00
Total Cost	$8,700.00